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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS*

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve ex officio as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

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*As revised and adopted at the Philadelphia meeting, January 1, 1941.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program, consisting of five (5) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:*—There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the Procedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches.* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings.

Root Distribution of Some Deciduous Fruit Trees in a California Orchard

By E. L. PROEBSTING, *University of California, Davis, Calif.*

THE study of the extent and distribution of roots has long been of interest to workers in agriculture, and while much has been done to clarify our knowledge of the factors affecting root behavior, our progress on this problem has been painfully slow. Although a knowledge of root distribution is important from many standpoints, particularly of absorption of water and nutrients, the inherent difficulties of making a study of this kind has delayed progress. The most widely used methods have been excavation of established root systems, observations of root growth along the walls of trenches or of glass-sided boxes, or growth in culture solutions. The first two involve disturbance of the root system. The second also presents difficulties in maintaining conditions at the soil-glass interface which are the same as in the interior of the soil mass, and the annoying habit of roots of turning back away from the plate and escaping observation. The last method provides growing conditions only remotely resembling field conditions. However, it is possible to determine cumulative growth by excavation, and to estimate activity roughly by measuring the rate of removal of water. This report indicates the type of root system found by excavation, and preliminary investigations of the factors responsible.

The trees examined were all growing in a deep, well drained Yolo soil, varying in texture from sandy loam to clay loam in the orchards of the California Agricultural Experiment Station at Davis, most of them growing under clean cultivation. Trenches were dug about 6 feet from the trunks of the trees and parallel with the tree row. Trench faces were marked off in 1-foot squares, and the permanent roots larger than about 1 millimeter were plotted for a distance of about 10 feet along the trench. It is, of course, recognized that only horizontal roots cutting the surface examined could be recorded, thus eliminating all vertical roots and those parallel to the trench face. Likewise, a negligible portion of the absorption probably occurs through roots of this size. The soil mass is permeated with fine roots, some of which may be permanent, but many of which are probably replaced each season if not after each irrigation. Sixteen trees (three cherries, two almonds, five apricots, one prune, two peaches, and three pears) were included, as well as observations on several others. These root counts showed very few roots in the surface foot, and most of those few in the 8- to 12-inch depth. Maximum root concentration occurs in most cases at 2 to 5 feet, with fewer roots below that depth. Typical distribution is shown in Fig. 1 for five apricot trees. Variations occurred between trees, but seemed as great within species as between them. Maximum penetration was not ascertained, but growth of apricot roots to 16 feet has been observed, and Veihmeyer and Hendrickson (3) have shown water withdrawal at a rapid rate to at least 12 feet under walnuts. Their studies show a general pattern for several species in uniform soil of very rapid use in the top 4 feet with

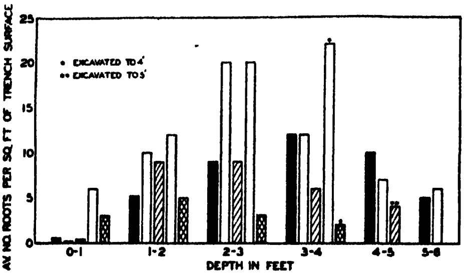

FIG. 1. Distribution of apricot roots.

slower rates at increasing depths to 12 feet. Although concentration of permanent roots is obviously not the sole factor concerned with the rate of water absorption, there is an apparent correlation. This might be associated with slower production of enough temporary roots to explore thoroughly a given soil mass from a smaller network of permanent roots. It is probable that lower temperatures and reduced oxygen concentration also affect the rate of absorption. Some evidence was obtained that more roots were present in the top foot under sod.

The distribution recorded from these excavations differs from the typical situation reported by others in more humid sections, the chief discrepancy being in the surface foot. This difference cannot be attributed to destruction by cultivation, since cultivation in this orchard is rarely deeper than 4 inches, and the low root concentration extends to a foot or 18 inches. Although rapid evaporation from the surface 6 or 8 inches might occur too soon to permit roots to explore it during the summer, this would not be true below that depth. And since irrigation replenishes the water supply from time to time, lack of moisture is unlikely to be the controlling factor.

A more probable limiting factor is high summer temperature. It has been shown by Nightingale (1) that peach and apple roots are unable to grow at high temperatures in sand culture. Smith (2) has reported soil temperatures at Davis high enough to inhibit root growth in the surface foot, on the basis of Nightingale's data. This factor was further examined in a manner similar to that used by Nightingale.

In order to obviate the possibility of a different response to temperature by roots in soil rather than in sand culture, Lovell peach seedlings were planted in loam in containers immersed in a series of six constant temperature baths at 45 degrees to 95 degrees F at 10 degree intervals. Twelve trees were started at each temperature. A typical tree from each set was washed out with a fine stream of water at intervals, dried and weighed. The growth curves are shown in Fig. 2 for the extremes and the most favorable temperatures. Growth at 55 degrees, 65 degrees, and 85 degrees was intermediate. Typical examples of growth and root condition are shown in Fig. 3. The roots in the higher temperatures were fibrous and suberized close to the tips. Those in the lower temperatures were thick, fleshy and white for several centimeters back from the tip. The larger root systems developed in the intermediate sets were normal.

A second series was set up in the same way, using Winter Nelis pear seedlings. These seedlings were much more variable than the peaches used in the first series. In the 95 degrees bath four died and

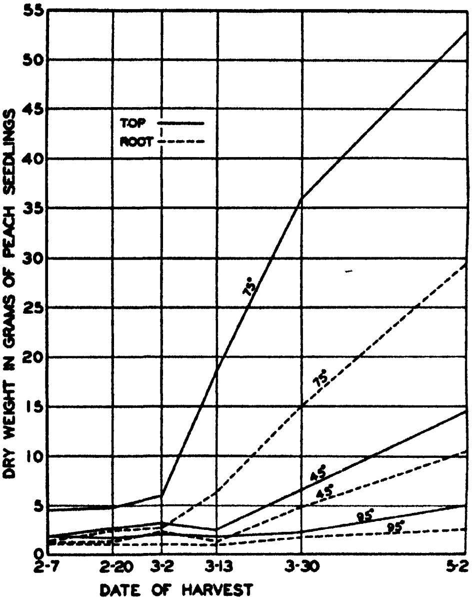

FIG. 2. Growth curves for peach seedlings in soil at constant temperatures.

two more showed distress, most of their leaves dying and dropping off. There was less contrast in appearance of roots in the different temperatures than was the case with peaches. The same tendencies were apparent, however, especially in the higher temperatures. No roots as thick and fleshy as were produced by the peach at 45 degrees were developed.

A parallel set of grape cuttings grown by Williams (4) showed a marked differentiation in root character of the same sort as the peach.

It is probable that feeder roots are developed in the surface soil during the late winter and early spring. The extent and duration of their activity has not been determined. This is of importance not only from the standpoint of normal nutrition but

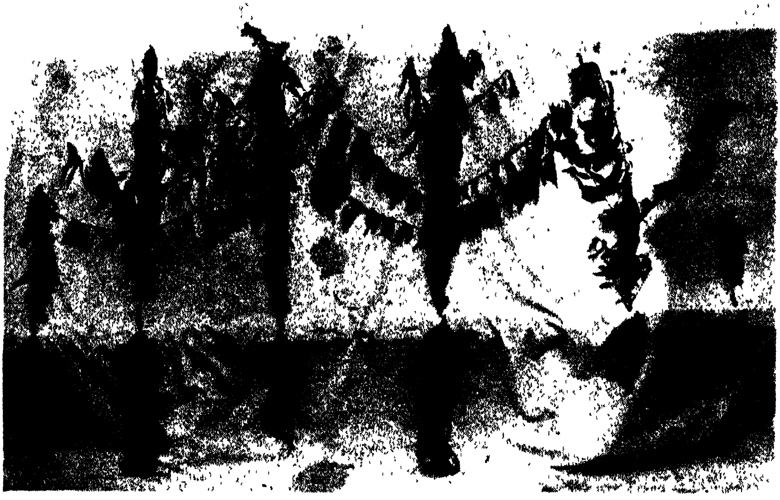

FIG. 3. Peach seedlings grown in soil at constant temperatures, left to right, 45 degrees F, 55 degrees F, 65 degrees F, 75 degrees F, 85 degrees F, and 95 degrees F.

also of absorption of fertilizers which may be fixed in the surface soil. There is some evidence that absorption may be negligible in this zone even where a high concentration of an element such as potassium has been built up over a period of years.

The data presented suggest that the small number of permanent roots in the surface foot of soil in a clean cultivated orchard at Davis is due to excessive soil temperature during the growing season.

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4. WILLIAMS, W. O. Unpublished data.

Beneficial Influence of Mulches on Two Years' Growth of Planted Black Walnut Varieties[1]

By THOMAS G. ŻARGER, *Tennessee Valley Authority, Norris, Tenn.*

MULCHING with straw has become a common practice with fruit growers. In the planting and care of grafted black walnut, mulch is being recommended. Repeatedly farmers have asked whether readily available materials, such as sawdust, would serve in mulching black walnut. Pointed evidence on this practical question appeared to be lacking. To test the relative value of several mulches for growth of black walnut, 75 trees were planted in the spring of 1941 on an old field near Norris, Tennessee. Black walnut trees which were used included 1-year-old grafts of B-23, Wanda, Booth, Ohio, Susan, Thomas, and Hepler on 3-year-old stocks. These varieties represent selections of value for tree-crop planting, but they are not under comparative test here. Immediately after planting, 1 pound of 4–8–4 fertilizer was applied in a 3-foot-radius circle about each tree.

Mulching treatments used in this test are as follows: new pine sawdust, well-rotted pine sawdust, new hardwood sawdust, well-rotted hardwood sawdust, wheat straw, broomsedge, sorghum pomace, and, untreated (check). Immediately after fertilizing, mulching materials were applied in 3-foot-radius circles around the trees to give settled depths of 2½ inches for sawdusts, and 4 inches for other materials. Mulches are being maintained annually.

Observations were made during the first growing season to give relative measures of conditions associated with the several mulches. Weed growth — chiefly dock, trumpetcreeper, greenbrier, horsenettle, paspalum, and sedge — was abundant around the untreated trees. Mulching had retarded weed growth generally: straw, pomace, and broomsedge effected marked reduction, and the pine sawdusts were somewhat less effective. Soil moisture content at a depth of 6 inches was measured at weekly intervals.[2] Soil under unmulched trees dried out in late August to below the wilting point. In soil under mulches of pomace, straw, new sawdusts, and broomsedge, the moisture content was markedly greater.

Height of black walnut trees was measured at time of planting, and again at the ends of the first and second growing seasons. Planted height ranged from 1.8 feet to 4.0 feet, by varieties; and averaged 2.7 feet. Height growth of trees averaged by mulching treatments (except pomace) is presented in Table I.[3] Trees mulched with pomace

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[1] This is a report of two years' progress on a study carried on by the Forest Tree Crop Unit, Department of Forestry Relations. Publication approved by Tennessee Valley Authority.

[2] With use of the method reported by Bouyoucos, G. J. and Mick, A. H. "An electrical resistance method for the continuous measurement of soil moisture under field conditions". Mich. Agr. Exp. Sta. Tech. Bul. 172. 1940.

[3] For these young trees, use of the index of stem diameter growth was not justified. Average stem diameter for all trees was 0.50 inches at time of planting, and 0.83 inches at the end of the second growing season.

TABLE I—SEASONAL HEIGHT GROWTH OF GRAFTED BLACK WALNUT TREES AVERAGED BY MULCHING TREATMENTS*

Mulching treatment	1941 Height Growth		1942 Height Growth	
	Total (Ft)	Difference, Mulched Minus Check (Ft)	Total (Ft)	Difference, Mulched Minus Check (Ft)
Broomsedge	0.56	0.09	1.33	0.86
Well-rotted pine sawdust	0.43	-0.04	1.17	0.70
Wheat straw	0.47	0.00	1.04	0.57
Well-rotted hardwood sawdust	0.47	0.00	1.03	0.56
New hardwood sawdust	0.57	0.10	0.87	0.40
New pine sawdust	0.50	0.03	0.78	0.31
Untreated (check)	0.47	0.00	0.47	0.00
Significant (at P =0.05)	——	0.28	——	0.50
Highly significant (at P =0.01)	——	0.38	——	0.66

*Based on 49 trees: seven treatments replicated in seven varieties.

grew 0.55 feet in height in 1941, and 1.02 feet in 1942; and comparable values for appropriate untreated (check) trees were 0.75 feet and 0.48 feet, respectively. None of the treatments had any significant effect on height growth for the first growing season. However, second-year growth of all mulched trees was better than that of unmulched trees. Broomsedge and well-rotted pine sawdust mulches stimulated height growth notably; and, straw and well-rotted hardwood sawdust mulches brought about increases which were just significant. Pomace, and the new sawdust mulches did not prove significantly beneficial in the first two years.

SUMMARY

From the brief two-year progress in this study certain benefits from mulching black walnut have been indicated. The recognized beneficial influence from use of common straw has been substantiated. Broomsedge mulch has notably stimulated height growth in the second season. Broomsedge proved a relatively efficient mulching material in reducing weed growth and conserving soil moisture. Well-rotted sawdusts have stimulated height growth. It is expected that the relative value of the sawdust mulches will be brought out more definitely in the next few years.

The Effect of Sod, Cultivation and Mulch Treatments on Soil Moisture, Soil Nitrates and Tree Growth in a Young Peach Orchard

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MANY experiments have been reported in the literature indicating the disadvantages of clean cultivation of orchard soils because of increased erosion and organic matter loss, especially on hilly sites. Various sod or sod-plus-mulch systems of soil managements are commonly used in apple orchards. The present trend is toward less cultivation of peaches. Several workers, Havis and Gourley (5), Johnston (8), Havis (4), and Burkholder (2), have indicated that under certain conditions peaches may be produced successfully under a sod or sod-plus-mulch system of culture. More experimental evidence is needed which gives accurate records of peach tree growth under such treatments.

The experiments being discussed in this report were designed to secure information on the growth and yield of peach trees under the following five systems of soil management: (1) sod plus mulch, (2) spring cultivation followed by a summer crop of soybeans and a winter cover crop of rye, (3) ladino clover sod, (4) orchard grass sod, and (5) a mixed sod of ladino clover and orchard grass.

MATERIALS AND METHODS

The data presented in this paper were secured from a peach orchard which was planted at the University of Connecticut in the spring of 1940. The ladino clover sod, orchard grass sod, and cultivation with cover crop treatments were applied to triplicated plots of six trees each, (three Elberta and three Halehaven) which were randomized over the orchard area. The mixed sod and sod-plus-mulch treatments were applied to 39 trees of several varieties, including Midway, Belle of Georgia, Early Elberta, Marigold, Redrose, White Hale, and New Jersey 109, 118, 124 and 128, planted along one side of the orchard.

The soil upon which this orchard was planted is a deep, well drained Gloucester fine sandy loam. The moisture equivalent of the top foot varied between 12.0 and 14.0 per cent. The average wilting percentage of the top foot is 5.3 per cent.

All sod plots were seeded down as soon as the trees were planted and were mowed two or three times during the early summer of each year. In the mulch plots, old hay was applied around the trees as soon as the sod became partially established. The mulch was renewed as often as necessary to keep down the growth of grass and weeds under the trees. The cultivated plots were disced several times during the spring after which a summer cover crop of soybeans was planted the first week of July. The soybeans were disced down and a winter cover crop of rye was seeded the first week of September. In late April all trees received an application of sodium nitrate at the rate of ⅓ pound for each year of tree age. Throughout the growing season, at irregular intervals depending on rainfall, soil samples were taken from all plots with a soil auger to a depth of 24 inches in the zone of soil occupied by the tree roots. The soil moisture was calculated from samples which were dried at a temperature of 105 degrees. Nitrates were determined by Morgan's (10) quick test on air dried samples. Organic matter was determined by the method of Schollenberger (11). Rainfall was recorded by the use of an official U. S. Weather Bureau rain gauge located at the edge of the orchard.

RESULTS AND DISCUSSION

Since the trees have completed only three season's growth, only a few scattered fruit have been produced. The yields were too small to indicate any differences between treatments.

The most significant differences in growth response between the various treatments are indicated by the trunk diameter measurements reproduced in Table I. It will be seen from these data that the tree growth is considerably better under cultivation with cover crops or sod plus mulch than under either a legume or non-legume sod without mulch.

TABLE I—TRUNK DIAMETER OF PEACH TREES

Treatment	Trunk Diameters (Cms)			
	Spring 1940	Spring 1941	Winter 1941	Winter 1942
Elberta Planted 1940				
Cultivation with cover crops	1.00	—	4.18	7.10
Ladino clover sod	1.00	—	3.14	5.06
Orchard grass sod	0.96	—	3.14	5.03
Halehaven Planted 1940				
Cultivation with cover crops	1.16	—	4.09	6.80
Ladino clover sod	1.18	—	3.30	5.26
Orchard grass sod	1.17	—	3.33	5.66
Mixed Varieties Planted 1940				
Mixed sod	1.54	—	3.90	5.76
Mixed sod plus mulch	1.55	—	5.21	7.87
Mixed Varieties Planted 1941				
Mixed sod	—	1.28	1.90	3.42
Mixed sod plus mulch	—	1.30	2.48	5.43

During the growing season of 1942, the amount of daily rainfall was recorded and tests were conducted to determine the moisture and nitrate content of the soil. The results of these tests are presented in Figure 1.

The soil moisture data indicate no significant differences between treatments and show that the moisture content was above the wilting percentage of the soil at all times during the growing season. Hendrickson and Veihmeyer (6, 7) have shown that the growth of fruit trees is not retarded by a lack of moisture until the water content of the

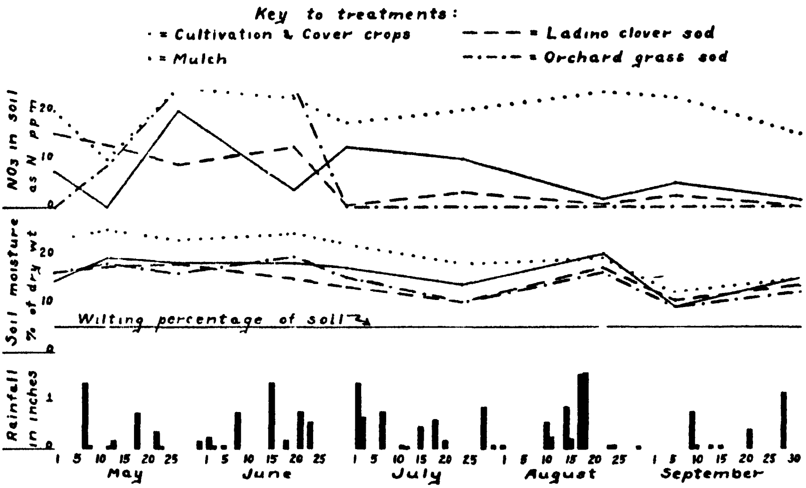

FIG. 1. Soil moisture, soil nitrates and rainfall in a three year old peach orchard with trees under four systems of soil management: (1) sod plus mulch, (2) cultivation with cover crops, (3) Ladino clover sod, and (4) orchard grass sod. Soil moisture and nitrate values under a mixed sod of Ladino clover and orchard grass were very similar to those under orchard grass alone and are not plotted in the above graph.

soil is reduced to the wilting percentage. It seems unlikely, therefore, that the differences in tree size in the present experiment were due to differences in soil moisture.

Soil nitrates were quite variable during May and June as indicated in Fig. 1, but during the middle of the growing season they seem to correlate rather closely with the growth status of the trees. As may be noted the soil nitrate content under the cultivation-cover crop system was higher than under orchard grass or Ladino clover sod throughout July, August, and September. The soil nitrate in the sod plus mulch plots was higher during July than under either sod treatment, but dropped by mid-August to about the same level as in the clover or grass sod plots.

Under the conditions of the present experiment the maintenance of a reasonably high soil nitrate level through July seems to be an important factor in encouraging vigorous tree growth. Although the peach trees growing in the sod plots were fertilized in the spring with sodium nitrate, the nitrates in the soil were at a very low concentration from late June to the end of the growing season. Other workers (1, 3, 9) have shown that the unsatisfactory behavior of sod-grown fruit trees was due to low soil nitrogen supply and not soil moisture. The data presented here may be of value in indicating the period of the growing season when soil nitrates may be critical in some soils under certain cultural treatments.

Soil organic matter as determined by the Schollenberger (2) method indicated no significant differences between treatments.

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An Economic Study of Orchard Tree Removal for Better Spacing[1]

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IN THE fruit districts of central Washington many apple trees have grown tall and in many instances are producing a minimum yield with a high percentage of low grade fruit. This is largely the result of close planting, which has resulted in a crowded condition of the trees. In the spring of 1940 an economic study of orchard-tree removal for better spacing was initiated at the Tree Fruit Branch Experiment Station at Wenatchee.

PROCEDURE

A 5-acre block of Winesap trees 35 years old was selected for this experiment. The effect on quality of fruit would have been more outstanding if Jonathan or Delicious trees had been used instead of Winesap, since the Winesap variety is one of the late-harvested fruits and the late fruits color better than do either of the other two varieties.

The original planting of the block of trees was 20 by 20 feet or 108 trees per acre. In 1925 when the trees were 20 years old, one-half of the trees had been removed, leaving a planting of 54 trees per acre. For the study the block was divided and one-half was left with 54 trees per acre and in the other section one-half of the trees were removed, leaving 27 trees per acre. For both blocks the general orchard practices such as irrigation, fertilizers applied, cover crops grown, spraying, thinning, and other practices were comparable.

Records were obtained for the years 1940 to 1942 inclusive from both the thinned and unthinned blocks of trees as follows: (a) production; (b) labor requirements; (c) operation requirements in equipment hours; (d) costs of labor, use of equipment and of materials based on 1940, 1941, and 1942 prices; (e) average net prices per box to growers for Winesap less storage and selling charges for 1940 and 1942 inclusive; (f) gross and net returns received from the close and open plantings based upon 1940, 1941, and 1942 costs and values; and (g) costs of materials, labor and equipment.

The production costs included all orchard operations but did not allow for interest and depreciation charges, repairs of equipment and orchard supervision. The operation costs and prices of fruit were determined upon the basis of wages prevailing for the season and upon fruit prices as of December 1 of each year involved.

PRESENTATION OF DATA

Production:—The production figures for the orchard area that was close planted and for the area upon which the trees had been spaced by removal of one-half of the trees are shown in Table I.

The data in Table I indicate that there was a rapid increase in the number of fruits produced per tree in both the close and open planted

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TABLE I—COMPARISON OF PRODUCTION OF FRUIT FROM CLOSE (54 TREES) AND OPEN (27 TREES) PLANTING

	1940		1941		1942	
	54*	27*	54*	27*	54*	27*
Average number fruits harvested per tree	1173	2212	2474	3163	3049	4221
Average size of fruit harvested per packed box	121	119	137	123	163	142
Average packed boxes, 42 pounds net, prematurely dropped per tree	3.3	3.4	2.2	3.4	0.8	1.5
Average total boxes, 42 pounds net, produced per tree, including dropped fruit	18.0	22.0	20.2	29.2	19.7	30.4
Total average number boxes per acre all fruits produced	972	594	1091	789	1064	821

*Number trees per acre

areas. No record of the number of thinnings was made the first two years, but in 1942, the average number of small fruits thinned from the open planted trees was approximately double that thinned from the close planted trees. The average size of the fruit was larger on the open planted trees, each year. As a result of the relatively heavy crop per tree, drop of fruit each season was heavier on the open than on the close planted trees.

Quality of Fruit:—The relationship of the tree removal and better spacing to the quality of apples subsequently produced is indicated by Table II.

TABLE II—QUALITY OF FRUIT AS AFFECTED BY THE TREE SPACING PROGRAM

Factors Considered	1940		1941		1942	
	54	27	54	27	54	27
Average per cent of "Extra Fancy" harvested	38.3	26.0	61.7	55.8	47.5	56.2
Possible per cent Extra Fancy*	82.1**	83.1	83.3	86.9	50.6	60.6
Number packed boxes per acre	684	412	902	659	852	696
Boxes harvested per acre according to grade:						
Extra Fancy	304	131	600	389	484	439
Fancy†	380	281	302	270	368	257
"C" Grade	54	44	30	14	88	46
Culls (including wormy fruit)	56	46	40	24	81	38
Culls (drops only)‡	178	92	119	92	43	41
Per cent production§	100	61	100	71	100	76

*Extra Fancy fruit plus fruit reduced because of codling moth stings; dropped fruit not included, graded on color only.

**Essentially no difference in possible Extra Fancy fruit first year because all fruit was well colored.

†Includes all Fancy fruit plus fruits sufficiently colored for Extra Fancy but with stings.

‡Of the total crop

§Per cent production in harvested crop of the tree spaced area compared with the crop of the close planted area.

The average per cent of the Extra Fancy apples harvested from trees of the open plot was much less than that from the trees of the close planted plot for the first two years of the experiment. This was the result of the increased number of Extra Fancy fruits with worm stings, which reduced them in grade. The possible per cent of Extra Fancy fruit from the two plots showed little difference the first year because all fruit was well colored. The second and third years, there were approximately 3 per cent and 10 per cent differences in favor of the thinned block. The percentage of Extra Fancy fruit was generally low in 1942, because the season was unfavorable for good coloring of apples. The trees in the open planting, with one-half of the original number of trees removed, the first year produced about 61 per cent of the total produced by the trees of the close planted block, the second year 71 per cent, and the third year 76 per cent.

Man Hours Labor Requirements:—A comparison between the close and open planted blocks of trees of the labor requirements in man hours for orchard operation is shown in Table III.

TABLE III—A COMPARISON BETWEEN CLOSE AND OPEN PLANTED APPLE TREES OF LABOR REQUIREMENTS IN MAN HOURS PER ACRE

Operation	1940		1941		1942	
	Man Hours for Close Planting	Man Hours for Open Planting	Man Hours for Close Planting	Man Hours for Open Planting	Man Hours for Close Planting	Man Hours for Open Planting
Pruning	45	22½	45	24	45	25
Brush removal	13½	6⅔	13½	7	13½	7½
Fertilizer applications*	1	½	1	½	1	½
Cultivating, seeding, ditching	5	5	5	5	5	5
Irrigating	36	36	36	36	36	36
Thinning	117	58½	124	70	213	141
Propping	5	2½	5	3	5	3½
Spraying, labor	113	62½	124	77	102	72
Harvesting	236	144⅓	300	210	276	213
Total Man Hours	571½	338½	653½	432½	696½	503½

*Some help was obtained from the tractor driver for this operation.

The data in Table III show that the large requirements for man hours of labor were for thinning, spraying and harvesting, and the greatest saving as a result of tree removal was in these operations. The operation costs with one-half of the orchard trees removed would not be reduced to one-half of that before tree removal because for only a part of the operations would there be a reduction in labor and materials. As a result of tree removal, the per cent saving in man hours for 1940, 1941, and 1942 was 40.8, 33.8, and 27.7 respectively, in comparison with the labor requirements of the block from which the trees were not removed.

Cost of Labor, Materials, and Use of Equipment:—The operation costs varied annually in part because of the differences in the costs of labor and materials on a per unit basis. In Table IV, the comparative costs of labor and materials and for the use of equipment have been based upon the prices prevailing for each year involved.

Average Net Prices Per Box to Growers:—The net prices per box received by the grower for the several grades of fruit from the crop produced by trees upon the close and open planted areas, figured upon the basis of average fruit price as of December 1 each year, are given in Table V.

In 1940 the net returns for the "Extra Fancy" and "Fancy" grades of Winesap were relatively low in comparison with the prices received in 1941, and less than half that received in 1942. In 1940 there were no net returns per ton from the "C" grade, culls, or drop apples. In 1941 the grower received almost as much for the "C" grade as he received in 1940 for the "Fancy" grade; and in 1942 he received

TABLE IV—Comparative Costs of Labor, Use of Equipment and Materials per Acre, for Close and Open Planted Areas, Based on Prevailing Prices Each Year

Expenditures for:	1940 (Dollars)		1941 (Dollars)		1942 (Dollars)	
	54 Trees	27 Trees	54 Trees	27 Trees	54 Trees	27 Trees
Pruning	13.50	6.75	18.00	9.60	22.50	12.50
Brush removal	4.00	2.50	5.33	3.00	6.65	3.33
Fertilizer application	.30	.15	.40	.20	.50	.25
Cultivating, seeding, ditching	1.50	1.50	2.00	2.00	2.50	2.50
Irrigation	10.80	10.80	14.40	14.40	18.00	18.00
Thinning	35.10	17.55	49.60	28.00	106.50	70.50
Propping	1.50	.75	2.00	1.20	2.50	1.67
Spraying (labor)	33.90	18.75	49.60	30.80	51.00	36.00
Harvesting	82.62	50.49	120.01	86.79	138.32	106.73
Total labor	183.22	109.24	261.34	175.99	348.47	251.48
Electric power for spraying	5.40	2.70	5.40	3.04	4.32	2.70
Tractor (including driver) for:						
Distributing fertilizer	1.40	.70	1.40	.70	2.00	1.00
Brush removal	1.40	1.00	1.40	.70	2.00	1.00
Cultivating, seeding, ditching	8.40	8.40	8.40	8.40	12.00	12.00
Distributing and collecting props	3.50	1.75	3.50	2.00	5.00	3.50
Distributing and hauling out boxes	24.30	14.85	27.28	19.73	31.92	24.63
Truck (including driver) for:						
Hauling boxes and apples	14.58	8.91	19.09	13.81	21.28	16.42
Total equipment	58.98	38.31	66.47	48.38	78.52	61.25
Total labor and equipment	242.20	145.75	327.81	224.37	426.99	312.73
Cover crop seed	1.58	1.58	1.58	1.58	1.58	1.58
Fertilizer	5.94	2.97	5.94	2.97	5.94	2.97
Spray Materials:						
Dormant	13.99	6.50	13.61	7.65	14.52	8.08
Calyx	3.89	1.94	4.10	2.31	4.97	3.11
Covers	77.59	38.75	76.31	42.93	66.50	41.55
Preharvest fruit drop	——	——	24.19	13.61	24.19	15.12
Total Materials	102.99	52.23	125.73	71.05	117.70	73.41
Water tax	4.50	4.50	3.50	3.50	3.50	3.50
Land tax	6.00	6.00	6.00	6.00	6.00	6.00
Total production cost*	355.69	210.28	463.04	304.92	554.19	395.64

*The total production costs in Table IV based upon the current prices for each year show savings of $141.45, $158.12, and $158.47 for the three years as a result of the tree removal. The cost of the materials and labor was increasingly higher in 1941 and 1942 than in 1940.

50 cents more per box for the "C" grade than he received in 1940 for the "Extra Fancy" grade. In 1942 the net price per ton received for the cull apples was only $17.50 less than he received in 1940 per ton of "Fancy" grade apples.

Comparative Gross and Net Returns:—The annual gross and net returns have differed not only upon the basis of variations in yield (Table I) but also upon the basis of costs of labor, materials, and use of equipment (Table IV) and upon the net returns to the grower per

TABLE V—The Average Net Prices per Box to Grower for the Several Grades of Winesap Apples Less Storage and Selling Charges

Grade of Fruit	1940 (Dollars)	1941 (Dollars)	1942 (Dollars)
Extra Fancy	1.10	1.25	2.25
Fancy	.95	1.10	2.05
"C"	0.00	.90	1.60
Culls per ton	0.00	15.00	21.50
Drops per ton	0.00	7.00	15.00

box for the different grades of apples (Table V). In Table VI, the comparative gross and net returns from the trees of the open and close planted areas have been based upon the costs and values prevailing for each year involved.

TABLE VI—COMPARISON OF GROSS AND NET RETURNS PER ACRE FOR CLOSE AND OPEN PLANTINGS, BASED UPON PREVAILING COSTS AND VALUES FOR EACH YEAR INVOLVED*

Factors Considered	1940— Value in Dollars		1941— Value in Dollars		1942— Value in Dollars	
	Close	Open	Close	Open	Close	Open
Extra Fancy	334.40	144.10	750.00	486.25	1089.00	987.75
Fancy	342 00	252.90	332.20	297.00	754.40	526.85
"C"	——	——	27.00	12.60	140 80	73.60
Culls (wormy)	——	——	12.60	7.50	36.55	16.99
Culls (drops)	——	——	17.50	13.50	13.55	12.90
Total value	676 40	397.00	1139.30	816.85	2034.30	1618 09
Packing expense and boxes	246 24	148 32	391.44	282.66	479.40	378 42
Total production expense	355 69	210.28	463.04	304.92	554.19	395 72
Total expense	601.93	358 60	854 48	587.58	1033.59	774 14
Net profit per acre	74 47	38 40	284.82	229.27	1000.71	843 85
Gain in favor of close planted	36 07	——	55.55	——	156 86	——

*If the comparison of gross and net returns had been figured on prices for labor, materials, and the sales for 1940, the gain in favor of the close planting would have been different: $36.07 in 1940, $44.00 in 1941, and a loss of $17 65 in 1942.

The net profit figured upon this basis was $36.07, $55.55, and $156.86 greater from the close planted area in 1940, 1941, and 1942 respectively than from the open planted area. If however, the costs and prevailing prices for 1940 had been used for the three years, a net profit would result the third year after tree removal as shown in Table VII.

TABLE VII—COMPARISON OF GROSS AND NET RETURNS RECEIVED FROM THE CLOSE AND OPEN PLANTINGS, BASED UPON 1940 COSTS AND VALUES

1940 Prices for:	1940— Value in Dollars		1941— Value in Dollars		1942— Value in Dollars	
	Close	Open	Close	Open	Close	Open
Extra Fancy @ 1.10	334.40	144.10	660.00	427.90	532.40	482.90
Fancy @ .90	342 00	252.90	271.80	243.00	331.20	231.30
"C" @ 0.00	0 00	0.00	0.00	0.00	0.00	0.00
Culls (including worms) @ 0.00	0.00	0.00	0.00	0.00	0.00	0.00
Culls (drops) @ 0 00	0.00	0.00	0.00	0.00	0.00	0.00
Total value	676.40	397 00	931.80	667.90	863.60	714 20
Packing expense per box @ .36	246.24	148.32	324.72	237.24	306.72	250.56
Total production expense	355.69	210.28	389.45	256.93	388.56	277.67
Total expense	601.93	358.60	714.17	494.17	695.28	528.23
Net profit per acre	74.47	38.40	217.73	173.73	168.32	185.97
Gain in favor of close planted	36.07	——	44.00	——	——	——
Gain in favor of open planted	——	——	——	——	——	17.65

The Basis of Calculation of Annual Costs:—Table VIII shows the basis of calculation used to obtain the cost data. These figures are based upon actual operations in the field. When the experiment was started in 1940, the orchard was extremely wormy from previous

TABLE VIII—Basis of Calculation, Cost of Actual Operation

Operation	1940 (Dollars)	1941 (Dollars)	1942 (Dollars)
Orchard labor per hour	.30	40	.50
Picking per packed box	.085	.11	.13
Distributing and hauling boxes from orchard	.025	.025	.03
Hauling to picking house—per box	.015	.075	.02
Tractor and driver per hour	1.40	1.40	2.00
Spray Materials per 100 Gallons:			
Dormant spray	.64¾	.63	67¼
Calyx spray	.18	.19	.23
1st and 5th covers	.36¾	.38¼	44⅓
2nd, 3rd, and 4th covers	.46½	48	.54¼
6th, 7th, and 8th covers	.48¾	44¼	50⅓
Hormone sprays	—	1.12	1.12
Electric power per 100 gal spray	.025	.025	0.25
Water tax per acre water	4.50	3.50	3.00
Real estate taxes per acre	4 32	4 32	4.32
Sulphate of ammonia fertilizer per lb	22	22	.22

carry-over codling moth pupae. An adjoining plot of Jonathan apple trees was 90 per cent wormy in 1939. The trees had not had proper care for the three years preceding the experiment and the orchard was on the verge of being considered marginal, hence the reason for the extra sprays in 1940 and 1941 as shown in Table IV.

Discussion

During the three years of the experiment, the total production of the close planted trees was relatively high, amounting per acre to 972 packed boxes the first year, 1091 the second, and 1064 the third. The block from which half the trees had been removed in the early spring of 1940 produced the first year 61 per cent of that of close planted trees, the second year 72 per cent, and the third year 77 per cent.

The indications, from the trend of production and the increase in the Extra Fancy fruit from the open planted trees in comparison with the close planted trees, are that the net returns from the former will be greater by the fourth or fifth year, with less labor and lower costs of production, than from the latter.

The total man hours of labor saved in producing a crop including harvest, on the spaced trees in comparison with the close planted trees, were 233 in 1940, 201 in 1941, and 193 in 1942. Approximately 40 per cent less labor was required to produce a crop through harvest on the open planting than on the close planting for the first three years after the tree spacing.

Advantages of a Tree Spacing Program:—(a) Reduction in labor for orchard management; (b) increased production of higher grade of fruit; (c) increased size of fruit; (d) less injury to trees from excessive pruning under crowded conditions; (e) increased production of fruit per unit; (f) improvement of soil through better cover crop growth; and (g) better control of insects and diseases.

Disadvantages:—Annual production reduced for several years, depending upon the production and condition of orchard at the time of tree spacing.

Soil and Water Conservation on Orchard Lands Within the Contra Costa Soil Conservation District

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THE Contra Costa Soil Conservation District was formed in December of 1941. It is composed of most of the central portion of Contra Costa County, just east of the San Francisco Bay area. Approximately 176,000 acres of land are included within the District.

TYPE OF AGRICULTURE

Several types of agriculture are found within that portion of Contra Costa County which is included in the District area. The orchard lands are in the valley floors, where the newer alluvial soils more suited to this type of agriculture are found. The moderate slopes rising from the valleys are used largely for the production of grain, hay, or pasture in conjunction with livestock enterprises. The steeper slopes and partially wooded hills provide permanent pasture for livestock. English walnuts make up the larger percentage of the orchards. Pears and prunes are next in order of importance. Some apricots and almonds are found within the District. There is also a considerable acreage of grapes, usually grown on the lighter soils and steeper slopes.

SOIL TYPES

The predominant soil types used for orchard land are the Danville, Yolo, Botello and Zamora loams and clay loams. Walnuts are grown also on Clear Lake and Tierra soils.

EROSION PROBLEMS

Rainfall.—The principal factor contributing to soil and moisture loss in this area is the amount and distribution of the rainfall. The average annual rainfall for the area is about 20 inches. It is usually distributed over a period of 3 or 4 months during the winter season. The first light rains of the season may be expected around the middle of November or the first of December. Heavy rains usually occur in January or February, with lighter rains in March and very little if any precipitation after the middle of April. This distribution of the rainfall necessitates a program that will enable the soil to absorb the maximum amount of the precipitation as it falls and prevent that which runs off from moving soil with it.

Erosion:—The amount of erosion and water run-off varies, of course, with soil types, slope groups and practices which have been followed in the past. In some vineyard and orchard areas on sandy soils, most of the topsoil has been removed, and the parent material has been exposed. A few farms have been abandoned in these areas; but, as a whole, erosion has not reached the stage in the orchard lands to cause very much alarm to the farmers themselves. Probably not more than 10 to 25 per cent of the topsoil has been removed from the larger part of the orchard lands with heavier soils.

Deposition:—Some damage is being done to orchard lands by deposition of silt from steeper lands above. In other cases, silt from orchards and vineyards has been deposited on county roads and other lands below.

COVER CROP PRACTICES USED

Three Government agencies are cooperating with the Contra Costa Soil Conservation District to develop a suitable program for soil and water conservation in orchard lands. The Extension Service has been active in encouraging the use of cover crops and fertilizers and in establishing experimental plots to determine the best materials to use. The Agriculture Conservation Association is active in the county, offering cash payment for adequate cover and green manure crops. The Soil Conservation Service has assigned technicians to the district for developing plans for increased war-time production through erosion control and water conservation on individual farms. The three organizations coordinate their work by frequent meetings and assisted the district directors in drawing up orchard cover crop recommendations for the district.

Annual Cover Crops:—Probably the most important step in controlling soil erosion and preventing water run-off on these orchard lands is to develop an adequate vegetative cover for the soil during the rainy season. Annual cover crops therefore are seeded in the orchards as early as is practicable in the fall, usually late in October or early in November. With the coming of the first fall rains, the crop starts its growth; and by the time the heavier rains are expected, late December or early January, the vegetation is established sufficiently to prevent erosion and increase water penetration.

Where erosion control is the primary factor, cereals alone are recommended. Barley and oats are the most popular cereals used. They are seeded at the rate of 80 to 100 pounds per acre.

On the heavier soils and flatter lands where erosion is more easily controlled, a mixture of a legume and a cereal generally is used. Purple vetch is the most successful legume planted, although some common vetch and fenugreek also are used. They are seeded at the rate of 40 pounds per acre, with 15 to 25 pounds of cereal, usually barley or oats.

The seed is either drilled or broadcast and covered with a drag or harrow. Combination seed drills and fertilizer spreaders are quite popular when fertilizer is applied, as the entire operation may be accomplished at once. The final operations with a cultural tool used in seeding the crop is always performed across the slope nearest the contour, to prevent accumulation of water in tracks down hill.

The farmers are encouraged to let their cover crops mature as late as possible in the spring before disking. This operations should, however, be done before the crop begins to compete with the orchard trees for the available moisture. As the last rains usually come during April, the cover crops generally are disked sometime during this month. Disking is recommended, rather than plowing, and should be limited to the extent that the cover crop residue is mixed with the surface soil instead of being turned completely under. This treatment forms a mulch very similar to the stubble mulch now being used in the wheat fields of the Pacific Northwest. The residue present in the surface soil is valuable in holding the soil particles together when the first rains come in the fall before the new cover crop has become established sufficiently to check erosion. This practice also allows more seed, particularly the cereals, to be matured; and it may be possible in some cases to seed a cover crop every other year and depend upon a volunteer crop during the alternate year.

Fertilization:—It is necessary to use a nitrogen — or nitrogen-phosphate-fertilizer on some of the poorer soils in order to insure a quick growth of the cover crop and thus provide maximum protection. Ammonium sulfate has been the most popular fertilizer when available, and it has been applied at the rate of 150 to 200 pounds per acre. A 41 per cent nitrogen fertilizer has been used quite extensively when ammonium sulfate has been unavailable. This material is put on at the approximate rate of 75 to 100 pounds per acre or the equivalent in actual nitrogen of amommium sulfate at the rates mentioned above. The fertilizer usually is applied at the time the cover crop is seeded, either through a seed drill provided with a fertilizer spreader attachment or with a broadcaster.

Perennial Cover Crops:—Relatively few of the orchards in this vicinity are irrigated. It therefore is necessary to conserve all of the water possible for the use of the trees. For this reason, permanent orchard cover crops have not been grown.

SUPPLEMENTAL PRACTICES

In order to control erosion satisfactorily on some orchard lands, it is necessary to include certain supplemental practices with the cover crop program. Diversion terraces or annual grade ditches are being relied upon to carry excess water around slopes to natural drainages or to constructed outlet ditches. These structures are built on ½ to 1 per cent gradients and serve to carry water from the orchard without washing. Grade ditches are constructed each fall with a Martin-V or other suitable equipment. Diversion terraces are permanent dykes of earth, which can be cultivated over. They need some maintenance each year to keep the dykes high enough to divert water.

It is essential that proper outlets be available for the water from either the terraces or the grade ditches. Permanent, vegetated outlet ditches are used for this purpose if natural waterways are not conveniently located to receive the water. Outlet ditches vegetated with Italian Rye grass and barley may be safely used on grades up to 4 per cent. Kikuyu grass has been used in a few cases and may prove successful on gradient steeper than 4 per cent.

Basin Listing:—Basin listing quite often is used in conjunction with the cover crop program. This operations is restricted to fairly permeable soils and to slopes under ten per cent.

Water Spreading:—In suitable locations, excess water that is carried from sloping land or from impermeable soils by means of terraces and outlet ditches is spread on permeable orchard soils below. Thus erosion is prevented on the sloping land above, and water conservation is achieved on the flat land below without damage from silt.

SUMMARY

It has been found that in the Contra Costa Soil Conservation District the following practices are effective in conserving soil and water and thereby maintaining and increasing war-time production: 1. Annual cover crops seeded early in the fall to provide a protective cover for the soil during the rainy season. 2. Cover crop residue mulch type of cultivation that will increase water penetration and reduce water run-off and erosion as well as lowering operation costs and wear on equipment. 3. Fertilization with a nitrogen, or nitrogen phosphate, fertilizer to insure a quick growth of the cover crop before the rainy season begins. 4. Contour cultivation on all sloping land, especially just prior to the rainy season. 5. Diversion terraces and annual grade ditches with proper outlets for the concentrated water. 6. Basin listing on suitable soils and slopes.

How Much Borax Can an Apple Tree Tolerate?

By L. P. LATIMER and G. P. PERCIVAL, *Agricultural Experiment Station, Durham, N. H.*

ASKEW and Chittenden (1) in New Zealand, Burrell (2) in New York, and McLarty (4) in British Columbia showed that internal cork of apples can be controlled by supplying the tree with boron as a top-dressing, by injection into the tree and by spraying the foliage with a water solution of borax previous to the incidence of the disease. Burrell (2) found, however, that bark injury occurred in the vicinity of the injection hole when ½ liter of a 1 per cent solution of borax or boric acid was injected into apple trees. A 5 per cent solution caused killing of some large branches. He also found lime included in borax or boric acid spray prevented injury to the foliage.

Top-dressing is now considered the most practical method of supplying fruit trees with boron, and the question has been raised concerning the minimum dosage that will cause injury to trees, foliage, and fruit. For this reason work was begun in 1940 to study the effect on apple trees of heavy borax applications.[1] Eighteen-year-old Delicious, Golden Delicious, and Wealthy apple trees growing in sod on a Charlton loam soil were selected for experimentation. Symptoms of internal cork had never been found in fruit from these trees although they were located not far from trees known to produce corky fruit. The amount of available boron in the soil under untreated trees was 0.5 parts per million, at harvest time (3), and fruit from untreated Golden Delicious trees contained 37.4 parts per million boron dry weight. With increased rates of borax application, made June 20, 1940, there was increased accumulation of boron in the fruit. Where 20 pounds of borax per tree had been applied, the content of available boron in the soil had by November 1940 increased to 16 parts per million, while fruit of Golden Delicious and Delicious contained, respectively, 176 and 131 parts per million, at harvest time. At given rates of borax application, Golden Delicious fruit generally accumulated more boron than Delicious. No adverse effects could be detected on fruit, foliage or tree during 1940 following even the heaviest borax applications. Fruit from trees receiving 20 pounds of borax kept as well in storage as that from untreated trees.

Table I shows the effects of broadcasting borax under the trees. The first noticeable injury from applications made in 1940 occurred in the summer of 1941. Definite injury occurred only on trees that had received 10 pounds or more of borax although there was some evidence that 5 pounds marked the borderline between safe and unsafe amounts to use. Twenty pounds of borax caused the greatest injury.

Trees which received 5 pounds of borax in 1940, or in both 1940 and 1941, were in good condition throughout 1942. Trees receiving 10 pounds of borax in 1940 only, seemed in 1942 to have recovered from their previous injury. Those receiving 10 pounds of borax in

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[1] The borax used in these experiments was contributed by the Pacific Coast Borax Company.

TABLE I—EFFECT OF BORAX TOP-DRESSING ON GOLDEN DELICIOUS AND DELICIOUS APPLES

Borax Per Tree (Pounds)		Condition of Tree and Fruit Summer and Fall	
Jun 1940	Jul 1941	1941	1942
½	0	Leaves large, dark green. Immature fruit green.	Leaves large, dark green. Immature fruit green.
½	½		
1	0		
1	1		
2½	0		
2½	2½		
5	0	Leaves large, some trees with green leaves and immature fruit. Others with pale green leaves and fruit.	Leaves large, dark green. Immature fruit green
5	5		
10	0	Some leaves small, pale to yellowish green or mottled yellow and green. Immature fruit yellowish.	Two trees with undersized leaves. Petiole angles narrow. Leaves green. Immature fruit pale green. Other trees apparently normal.
10	10	Some leaves small, pale to yellowish green or mottled yellow and green. Immature fruit yellowish.	Immature fruit yellow.
20	0	Leaves small, pale yellow between greenish veins. Immature fruit yellow. Small foliage gives tree lacy appearance.	Leaves undersized, pale green, narrow. Narrow petiole angles. Immature fruit yellow. Lacy appearance to trees.
20	20	Leaves small, pale yellow between greenish veins Immature fruit yellow. Small foliage gives tree lacy appearance.	Leaves small, narrow, pale green with some tip-burn Leaves stand upright on trees giving trees very open or lacy appearance. Imuremat fruit yellow. One tree with several branches killed.

both 1940 and 1941, showed injury in 1942. Trees which received 20 pounds of borax in one or both years showed injury in both 1941 and 1942.

The foliage of injured trees appeared quite yellow in 1941. Closer examination showed that the interveinal areas were yellow while the veins alone appeared as thin green lines. Leaves on injured trees were diminutive in size, giving the trees an open, lacy appearance. Although the leaves were again small in 1942, they were pale green in color and never became yellow as in the previous year. In both 1941 and 1942, immature fruits on trees receiving 10 or 20 pounds of borax were always yellow. In 1942, dead branches and tip-burned leaves were found in one tree which had received 20 pounds of borax in both 1940 and 1941. No other tree showed like injury.

In the orchard in which the above experiment was performed, wild strawberry plants were severely injured even with 2½ pounds of borax per tree. Ten pounds of borax killed the plants. Grass was less sensitive but was badly injured with 10 pounds of borax and killed with 20 pounds.

Since internal cork may be prevented by borax sprays, the question arose whether strong borax solutions might injure fruit or foliage. In 1941, 6 weeks after petal fall, trees which had never previously been subjected to any borax treatment were sprayed with different strengths of borax (Table II). No lime was used in these sprays which were applied on a sunny day when the shade temperature was 80 degrees F. The spray dried-on the foliage within 30 minutes. The only injurious effect was early yellowing of leaves and defoliation in trees sprayed with a saturated solution of borax. It is possible that some injury might have occurred had the trees been sprayed earlier in the season.

TABLE II—EFFECT OF SPRAYING BORAX ON DELICIOUS, GOLDEN DELICIOUS, AND WEALTHY TREES

Strength of Borax Spray Applied July 17, 1941 (Pounds in 50 Gallons of Water)	Borax Per Tree (Pounds)	Condition of Tree and Foliage 1941 and 1942	
		Tree Sprayed	Sod Sprayed
2½	0.62	Excellent	Excellent
5	1.25	Excellent	Excellent
10	2.50	Excellent	Excellent
25	6.25	Excellent	Excellent
Saturated solution	(?)	Excellent	One tree with scorched leaves

The same concentrations of borax were also sprayed on the ground under certain other trees. No injury resulted from these treatments. One tree showed scorched foliage in 1941 and 1942 but this condition is attributed to other causes.

In another test, five different soils were planted to Wealthy apple seedlings in the greenhouse. Borax was applied to each soil as indicated in Table III. Soils A, B, D, and E were obtained under trees which produced fruit badly affected with internal cork. Soil C was a Hermon loam known to be naturally adequately supplied with boron and was apparently well enough buffered that better growth and less injury occurred from heavy borax applications than in the other soils. Soil D was from the same orchard as soil E but had been previously heavily fertilized with calcium cyanamid. Soils A and B were from different orchards in distant parts of the state. The different response of these soils to boron treatment is clearly illustrated. The more acid soils were found lacking in their capacity to fix boron. Even light

TABLE III—GROWTH OF APPLE SEEDLINGS IN GREENHOUSE (3 MONTHS OLD)

Boron (Pounds Per Acre)	Height of Trees (mm)				
	Soil A	*Soil B*	*Soil C**	*Soil D*	*Soil E*
None	450	65	325	270	456
5	460	165	455	475	92
10	210	196	422	555	102
15	174	40	350	565	80
20	55	38	525	393	48
30	53†	26†	405	260	65
40	33†	42	57	190	50
50	34†	35†	48	87	—
pH	5.1–5.6	4.5–4.6	5.1–5.5	7.1–7.3	4.5–4.7

†—plants died.
*Soil not deficient in boron in field.

applications of borax proved toxic to trees growing in them. Soil D, to which sufficient calcium cyanamid had been added to raise the pH to 7.1 rendered heavier applications of borax less toxic.

DISCUSSION

The foregoing evidence is presented to substantiate the view that it is important to consider the pH value of the soil when interpreting results of top-dressing with borax and when recommending safe amounts to use in an orchard or part of an orchard. Previous treatment, rainfall, drainage, leaching, content of organic matter, and buffering power of the soil should also be considered. Investigations comparing sod with a cultivated surface would also be of value in studies on top-dressing orchard soils with borax. Differences in the amounts of borax necessary to cause injury to cultivated annual crops compared to orchard trees growing in sod may be marked, and this subject needs further investigation.

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Some Further Observations Concerning Injury to Apple Tree Foliage Induced by Applications of Calcium Cyanamid[1]

By R. H. SUDDS and R. S. MARSH, *West Virginia University, Morgantown, W. Va.*

THIS report presents observations made during 1943 on injury to the foliage of mature York Imperial apple trees induced by soil applications of calcium cyanamid. A similar occurrence in the same orchard was observed in 1937 (1); that source should be consulted for the details of the experimental layout in which cyanamid is one of four nitrogen-carriers under test. The moderately vigorous trees are fairly representative of the condition of other trees in the same age-group in average orchards of the district.

DETAILS OF APPLICATION OF THE CYANAMID

Applications of 5¼ pounds of cyanamid have been made annually to each of the 20 randomized single-tree plots receiving this treatment. In 1938, 1939 and 1940, the cyanamid was applied in the autumn while spring applications were made in the last four years. After the appearance of scorch in 1937 on the foliage of the trees receiving cyanamid, four similar even-age trees not previously utilized in the experiment were selected to receive applications of 21 and 23 pounds of cyanamid per year. With all of these trees, the nitrogen-carrier has been applied in the usual fertilizer rings extending approximately from the tips of the branches towards the trunks of the trees. In all, there were 20 trees receiving 5¼ pounds of cyanamid (the approximate equivalent of 7 pounds of the standard of comparison, Chilean nitrate of soda), three of 21 pounds, and one of 25 pounds. Due to a misunderstanding, all cyanamid trees received two applications, spring and fall, in 1940. In spite of this error, no trace of foliage injury attributed to cyanamid appeared during the period of 1938 to 1942, inclusive.

APPEARANCE OF FOLIAGE INJURY IN 1943

On June 2, 1943, the first symptoms of cyanamid injury were observed on the foliage of the 21- and 25-pound trees; this was followed presently by the slower and less intensive development of burning on the 5¼-pound individuals. Only the southeastern half of the 25-pound tree, the largest individual in the orchard, was affected; the leaves on this portion exhibited severe marginal and tip burning followed in many instances by a tight curling or rolling of the edges. In the case of the comparatively smaller 21-pound trees, the injury was general over the whole periphery. By autumn, considerable defoliation occurred especially with certain individual branches. With the 5¼-pound group, chiefly the typical first-stage cyanamid tip burn was evident and this was generally localized in certain areas, altho here and there whole scaffold limbs or large lateral branches showed the more advanced stage of marginal necrosis and occasionally the tight rolling of the edges. None of the 5¼-pound trees exhibited scorching over the entire top. The affected areas bore no consistent relationship to the direction of exposure or to the relative vigor of the individual trees. No such symptoms were observed on the trees receiving any of the three other nitrogen-carriers, namely, Chilean nitrate of soda, sulphate of ammonia, and urea (or Uramon). By early October it was possible with only a single exception to pick out, by the foliage injury, every randomized tree of those receiving cyanamid.

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The photograph, Fig. 1, exhibits representative leaves from the trees receiving 21 pounds of cyanamid; this would also represent a small part of the leaves on the 5¼-pound individuals. The ventral side is shown because the photographs of the dorsal surface failed to show adequately the sharp line of demarcation between living and dead tissue.

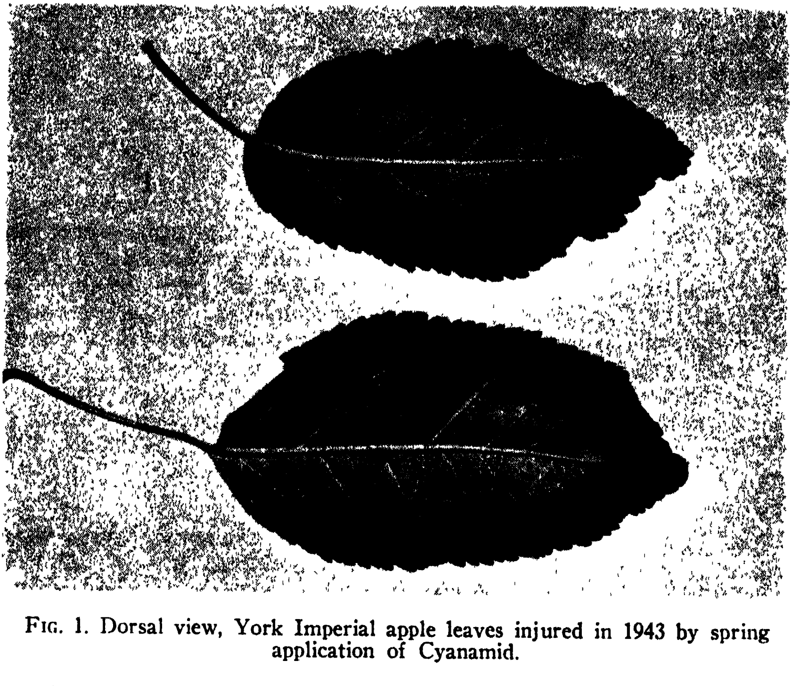

FIG. 1. Dorsal view, York Imperial apple leaves injured in 1943 by spring application of Cyanamid.

EFFECT OF APPLICATIONS OF POTASH ON CYANAMID INJURY

Chemical analyses of the soil in this orchard had indicated a very low degree of base saturation. Since a potash-deficiency has been shown to accentuate injury from nitrogenous fertilizers, especially after applications of lime or cyanamid, it was decided in consequence of the earlier injury to build up the supply of exchangeable bases in the soil. In the spring of 1941 and again in that of 1942, 4 pounds of muriate of potash and 4 pounds of sulphate of potash were broadcast in rings under the spread of the branches of 10 of the 20 trees receiving 5¼ pounds of cyanamid. The material was not worked into the soil in any manner. These potash applications as applied had absolutely no effect on the incidence or amount of the foliage injury; the only 5¼-pound cyanamid tree that failed to show any leaf scorch was one that had received no potash.

EFFECT OF APPLICATIONS OF MAGNESIUM SULPHATE ON CYANAMID INJURY

Since as previously stated all exchangeable bases were low in this orchard soil and since magnesium-deficiency can readily be confused with potash-deficiency, toxic sprays, or fertilizer injury, 4 pounds of magnesium sulphate were applied in the autumn of 1941 and in the spring of 1942 to every tree regardless of the nitrogen-carrier in the fertilizer experiment, including the 21- and 25-pound cyanamid trees. As in the case of the potash applications, it was not practical to work this into the soil. All that can be said of the magnesium sulphate is that as used it did not prevent the incidence of leaf injury. The possibility of a magnesium-deficiency was not eliminated by the applications of magnesium sulphate.

CONDITIONS RESPONSIBLE FOR FOLIAGE INJURY

While the 21- and 25-pound rates of application of the cyanamid were purposely excessive, the spring application of 5¼ pounds per tree is well within reasonable limits for the Cumberland-Shenandoah Region. That amount per tree has produced foliage injury following spring applications twice during the growing seasons of 1937–1943, inclusive.

While the effect of the ring application in concentrating the cyanamid on a relatively small area of soil was undoubtedly a factor in inducing the injury, or at least in influencing its degree of severity, this is, nevertheless, the standard method of applying the various nitrogen-carriers in the Cumberland-Shenandoah Region.

In 1943, as in 1937, weather conditions apparently were responsible for the visible development of cyanamid injury to the foliage. The foliage injury reported previously had followed an application of cyanamid on March 26, 1937, of 5¼-pounds per tree. (This date was approximately one month before bloom.) It was assumed in that instance that one of the potentially contributory causes of the undesirable reaction might have been the lack of sufficient precipitation for a considerable period of time in the spring, both before and after the application of the cyanamid; this was based on the assumption that some of the material might have been converted to dicyandiamide while lying indefinitely on the dry soil surface.

The foliage injury observed in 1943 followed the application of the cyanamid on March 22. The precipitation for the balance of March was only 0.11 inches. Through April 18, 0.77 inches fell, of which 0.30 was the maximum at any one time. As was suggested following the 1937 injury, the cyanamid might have changed chemically during this time. From April 19, 1943, through the April 21, 2.70 inches of rain fell to end the dry period. Subsequent precipitation should have been adequate at least until the scorch began to appear on June 2.

March temperatures were approximately normal and April was 2 degrees colder than normal. Therefore, in 1943 unusually high temperatures during the period when the cyanamid might have been lying on the soil surface could hardly have been a contributing factor in the resultant injury.

The orchard has not been limed, at least since the site was planted in 1911. The pH of the surface soil under the spread of the branches of the cyanamid trees averaged about 5.5, a value not at all uncommon in commercial orchards of the Shenandoah Valley.

The owner of the orchard applied an inconsequential amount of stable manure to the entire orchard, including the experimental block, in 1938. This was not incorporated into the soil but was left lying on the soil surface.

DISCUSSION

This fact, rather obvious by now, should be stressed: There is no way of predicting the appearance of foliage injury following spring applications of cyanamid even when the trees receive annually altogether unreasonable amounts of that nitrogen-carrier. In 1943, the injury was produced at least to some degree with all amounts in use, namely, 5¼, 21, and 25 pounds per tree. As observed previously, the two heavier rates induced much more severe injury than did the smallest amount. In 1937, when only the 5¼-pound rate of application of cyanamid was employed, the resultant foliage injury was considerably more severe than that observed on the same trees in 1943. In 1940, duplicate fall and spring applications each of 5¼, 21, and 25 pounds of cyanamid induced no signs of foliage scorch.

The evidence presented in this report, in the previous one (1), and elsewhere, all tend to confirm the opinion that cyanamid is a most temperamental nitrogen-carrier.

SUMMARY

Spring applications of cyanamid in reasonable amount applied under the spread of the branches have resulted in foliage injury two seasons out of seven to mature York Imperial apple trees in a representative apple orchard in the Eastern Panhandle of West Virginia. Chilean nitrate of soda, sulphate of ammonia, and urea (or Uramon) used in equivalent amounts in the same block of trees have induced no such injury during the same period.

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Influence of Climatic Conditions on Date of Full Bloom of Delicious Apples in the Wenatchee Valley[1]

By GEORGE P. SISLER and E. L. OVERHOLSER, *State College of Washington, Pullman, Wash.*

IN planning orchard work in the spring and in determining apple blossom festival dates, it is helpful to be able to estimate the date of full bloom with a reasonable degree of accuracy, several weeks in advance. Hence, data pertaining to the temperature, cloudiness of days, precipitation, and depth of snow in the nearby mountains have been assembled and an effort made to relate these with the full bloom dates of Delicious apples in the Wenatchee valley for the years 1926 to 1943, inclusive.

OBSERVATIONS AND DATA

Chilling Requirements of Resting Buds:—Wooten (1), upon the basis of weather data for the years 1925 to 1938 inclusive, reported that in central Washington (latitudes 46° to 49°) even with mild winters there are in excess of 50 days following normal leaf drop when the temperature averages 41 degrees F or lower to meet the chilling requirements and thus to completely break the rest period of apples before climatic conditions normally become favorable for the buds to respond (2).

Temperature:[2]—For study with Delicious apples grown in the latitude of central Washington a maximum temperature of 43 degrees F was taken as the minimum growth limit. The growth functions were considered as beginning when the daily temperature rises above 43 degrees F.

Temperature data and dates of full bloom of Delicious apples have been assembled in Table I. To place the different years upon a comparable basis, the "accumulated temperatures" above a maximum of 43 degrees F beginning with February 1 to date of full bloom are shown. For instance, if the maximum temperatures for the first three days of March were 45 degrees, 48 degrees, and 53 degrees F, they would represent 2 degrees, 5 degrees, and 10 degrees F respectively above a maximum 43 degrees F or a total of 17 of maximum degrees in excess of 43 degrees F. Taking the data of the years from 1926 to 1943 inclusive as a basis, the degrees of "accumulated temperatures" above 43 degrees F maximum from February 1 until Delicious apple buds reached the full bloom stage of development[3] ranged from 922 to 1148. The data in Table I show a fairly close correlation between "accumulated maximum temperatures" above 43 degrees F beginning February 1 and date of full bloom of Delicious apples. The authors

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[1] Published as Scientific Paper No. 568, College of Agriculture and Agricultural Experiment Station, State College of Washington.

[2] Weather records are from the United States Weather Bureau Station at Wenatchee City Pumping Plant and are published in Climatological Reports.

[3] Full bloom was determined as that stage of development when the first petals began falling naturally.

TABLE I—COMPARISON OF TEMPERATURES AND DATES OF FULL BLOOM OF DELICIOUS APPLES IN THE WENATCHEE VALLEY

Year	Date of Full Bloom	Accumulated Degrees Above a Maximum of 43 Degrees F From February 1	
		To April 1	To Full Bloom
1926	Apr 14	801	1148
1927	May 1	408	1075
1928	Apr 28	582	1106
1929	May 2	484	1110
1930	Apr 19	588	1086
1931	Apr 27	404	966
1932	Apr 28	316	964
1933	May 1	305	956
1934	Apr 11	778	1065
1935	May 1	333	941
1936	Apr 25	307	922
1937	May 4	317	986
1938	Apr 28	315	982
1939	Apr 24	444	1055
1940	Apr 19	590	1037
1941	Apr 18	695	1078
1942	Apr 23	427	1016
1943	Apr 28	359	1027

realize that the use of average temperature for a day as determined by averaging the 24 values of hourly temperatures observed during that day may have provided a more accurate means of predicting full bloom than the use of "accumulated degrees of temperature" above a maximum of 43 degrees F. Records were not available, however, to permit this being done.

The higher the number of degrees of "accumulated temperatures" above 43 degrees F on April 1, the greater will be the tendency for earlier blossoming. This is illustrated by the years 1926 and 1934 when the accumulated temperatures above 43 degrees F on April 1 were 801 and 778 respectively and dates of full bloom were April 14 and April 11. These are outstandingly the years of earliest bloom. The years 1930, 1940 and 1941 by April 1 had the next highest number of degrees of accumulated temperatures, that is, 695, 590, and 588, and likewise were the years of next earliest date of blossoming, full bloom occurring April 18 in 1941 and April 19 in the other two years.

When the number of "accumulated degrees" of temperature above a maximum of 43 degrees F from February 1 to April 1 or "growing temperatures" approximated 780 degrees or above, the date of full bloom was before April 15. This was true both years, 1926 (801 degrees F) and 1934 (778 degrees F).

When the "growing temperatures" from February 1 to April 1 approximated 590 to 700 degrees F, the dates of full bloom were April 18 or 19, three times out of four years, *viz.*, 1930 (588 degrees F), 1940 (590 degrees F) and 1941 (695 degrees F). The exception was in 1928, when a cold April apparently retarded development. The average daily number of degrees above 43 degrees F was only 18.7 degrees F, the lowest of any of the 18 years.

When the "growing temperatures" from February 1 to April 1 approximated 430 to 500 degrees F, the dates of bull bloom were April 23 or 24 two times out of three years, *viz.*, 1939 (444 degrees F) and

1942 (427 degrees F). The exception was in 1929, when there was the second coldest April of the 18 years.

When the "growing temperatures" from February 1 to April 1 approximated 300 to 410 degrees F, the date of full bloom was from April 27 to May 1 seven times out of nine, *viz.*, 1927 (408 degrees F), 1931 (404 degrees F), 1932 (316 degrees F), 1933 (305 degrees F), 1935 (333 degrees F), 1938 (315 degrees F), and 1943 (359 degrees F). The two exceptions were in 1936, when April was somewhat warmer than usual, (average daily number of degrees above 43 degrees F was 24.6 degrees F) and in 1937, which had the third coldest April of the 18 years.

The data in Table I show that when the accumulated temperatures above 43 degrees F from February until full bloom of the Delicious were in excess of 1000 degrees F, the dates of full bloom varied from April 11 to May 2. When the accumulated temperatures above 43 degrees F were less than 1000 F, the dates of full bloom varied from April 25 to May 4, inclusive.

During the five years (1932, 1935, 1936, 1937, and 1938) when the accumulated temperatures above 43 degrees F from February 1 to April 1 were relatively low, 316, 333, 307, 317, and 315 degrees respectively, the dates of bloom were also relatively late, varying from April 25 to May 4. Obviously the weather occurring after April 1 influences the date of full bloom as well as that occurring before this date.

Character or Cloudiness of Days:—The mean daily temperature is not an exact measure of the temperature of the twigs and buds of apple trees because on calm days in clear sunlight, these may have a temperature considerably above that of the surrounding air. Strong winds tend to keep the temperature of the twigs down to approximately the same as that of the air even on sunny days. Haziness prevents the twigs from becoming as warm as they would in sunlight and during cloudy or foggy days the twig and air temperatures are essentially the same.

Weather observers classify character of days as to cloudiness by means of a series of numbers from 0 to 10, the 0 referring to no clouds while 10 means entirely overcast. Days referred to as 0, 1, 2, and 3 would be classified as clear; those referred to as 4, 5, 6, and 7 as partly cloudy; and those referred to as 8, 9, and 10 as cloudy. In Table II the number of cloudy, partly cloudy, and clear days are recorded. The cloudiness index number referred to in Table II was computed as follows: The number of clear days was multiplied by the average of 0, 1, 2, and 3 or 1.5; the number of partly cloudy days was multiplied by the average of 4, 5, 6, and 7 or 5.5; and of cloudy days, by 9. These totals were added and the result divided by the total number of days from February 1 to date of full bloom. By comparing the various years, it will be seen that they are all similar, the clearest seasons being 3.8 in the years 1929 and 1934 while the cloudiest season occurred in 1938, which had an index number of 5.6. With a variation of but 1.8 points in the cloudiness index between the cloudiest and the clearest years,

TABLE II—Comparison of Cloudiness of Days, Precipitation, and Depth of Snow With Date of Full Bloom of Delicious Apples in the Wenatchee Valley

Year	Date of Full Bloom	Cloudiness of Day from February 1 to Full Bloom					Precipitation (Inches)	Depth of Snow on March 1 at Blewett Pass (Inches)
		Total No. of Days	No. Cloudy	No. Partly Cloudy	No. Clear	Cloudiness Index		
1926	Apr 14	73	10	34	29	4.4	1.30	No record
1927	May 1	90	19	28	43	4.3	1.53	No record
1928	Apr 28	88	23	28	37	4.7	.82	14
1929	May 2	91	16	22	53	3.8	.98	32
1930	Apr 19	78	9	39	30	4.4	1.64	26
1931	Apr 27	87	23	30	34	4.9	.64	18
1932	Apr 28	88	19	45	24	5.2	1.23	29
1933	May 1	90	22	35	33	4.9	1.15	64
1934	Apr 11	70	10	22	38	3.8	.69	21
1935	May 1	90	21	31	38	4.6	.80	47
1936	Apr 25	85	15	41	29	4.8	1.45	64
1937	May 4	93	30	37	26	5.5	4.50	67
1938	Apr 28	87	31	30	26	5.6	3.89	82
1939	Apr 24	83	16	31	36	4.4	1.56	67
1940	Apr 19	79	25	29	25	5.3	2.89	46
1941	Apr 18	77	21	22	34	4.7	1.87	31
1942	Apr 23	82	21	30	31	4.9	2.01	45
1943	Apr 28	87	33	26	28	5.5	.91	No record

possibly but little influence could be expected upon the date of full bloom.

Nevertheless, with the years of earliest date for full bloom, that is, 1934, 1926, and 1941, the cloudiness indices all were relatively low—3.8, 4.4, and 4.7 respectively. With the years when the date of full bloom was the latest, that is, 1937, 1929, 1927, 1933, and 1935, the cloudiness indices were relatively high only two years out of the five years that full bloom was not attained until May (1933 and 1937). In 1927, the total degrees above 43 degrees F from February 1 until April 1 was relatively low (408 degrees F); in 1935 the total degrees above 43 degrees F from February 1 until April 1 and also until full bloom, May 1, were both relatively low, that is, 333 and 941 degrees F respectively. The air temperatures during 1927 and 1935 were so low that the possible influence of the relatively low cloudiness index was insufficient to adequately compensate for the cool temperatures. The date of full bloom in 1929 was relatively late, May 2, notwithstanding a low cloudiness index and a relatively high total degrees above 43 degrees F from February 1 to date of full bloom (1110 degrees F). The relatively low total degrees (484 degrees F) from February 1 until April 1 may have been the principal retarding influence. Under Wenatchee weather conditions, using data of the past 18 years as a basis, the cloudiness of the days appears to influence slightly the date of full bloom. This is secondary to the direct influence of air temperature.

Precipitation:—A record of the amount of precipitation occurring from February 1 to the date of full bloom is tabulated in Table II. The precipitation varied from .64 inches in 1931 to 4.50 inches in 1937. There appears, however, to be little or no correlation between the amount of precipitation and the date of full bloom. It is possible that in 1937 when the most precipitation occurred that it may have to some extent contributed to the delay in the date of full bloom (May 4) but low temperatures and cloudy weather were the more important influences. In 1929, however, there was only .98 inches of precipitation yet the full bloom date occurred on May 2. Likewise in 1926, and 1927, the amount of precipitation was 1.30 inches and 1.53 inches respectively or almost the same, yet the full bloom dates occurred 16 days apart. The opposite influence might be indicated by comparing the years 1940 and 1943. The later year had only one-third the precipitation of that received in 1940, yet the full bloom occurred nine days later.

Snow in the Mountains:—Some fruit growers have thought that the amount of snow in the mountains on March 1 might influence the season's development. To check this factor, weather bureau records were obtained giving the depth of snow on March 1 at the top of Blewett Pass in the Cascade Mountains, approximately 20 miles from Wenatchee. These records are included in the last column of Table II. The depth of snow varied from 14 inches to 82 inches. In the years both of these extremes occurred, however, the date of full bloom fell on April 28. By comparing the various years no correlation was evident between the depth of snow and full bloom date.

SUMMARY

From available weather records, the "accumulated temperatures" from February 1 until April 1 and until full bloom, the relative cloudiness and precipitation from February 1 until full bloom, and the depth of snow on March 1 at Blewett Pass in the Cascade Mountains were studied to estimate their possible influence upon the date of full bloom of Delicious apples in the Wenatchee district.

Of the four climatic factors considered during the interval of time involved, air temperature, only, appeared to have any definite and fairly consistent influence upon the date of full bloom of Delicious apples in the Wenatchee valley.

A total of approximately 1000 degrees F of accumulated temperatures, above a daily maximum of 43 degrees F from February 1 was required to bring Delicious apples into full bloom.

When the "accumulated temperatures" above 43 degrees F from February 1 to April 1 were approximately 700 degrees F or above, the dates of full bloom of the Delicious varied from April 11 to April 18; with accumulated temperatures of only 333 or less, the dates of full bloom varied from April 25 to May 4.

An analysis of the data suggests that unless the temperatures during April are either unseasonally cool or warm that certain generalizations as to date of full bloom of mature apple trees in the Wenatchee district, based upon the "accumulated degrees" of temperature above 43 degrees F, from February 1 to April 1, can be made as follows: (a) 780 degrees F and above, before April 15; (b) 585 to 700 degrees F, April 18 to 20; (c) 430 to 500 degrees F, April 22 to 25; and (d) 300 to 410 degrees F, April 27 to May 2.

While the influence was relatively small, there appeared to be some slight effect from the relative cloudiness of the day, clear days tending to hasten the date of full bloom.

The amount of precipitation in the Wenatchee valley and the depth of snow on March 1 in Blewett Pass has no measurable influence on the date of full bloom of Delicious apples in the Wenatchee district.

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The Relationship of Late Blossoming to Frost Injury in the Apple

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AVOIDANCE of injury from spring frosts through extensive use of late blossoming varieties of apples has rarely, with the possible exception of certain varieties grown in France, been consciously attempted, probably because there are few varieties that combine the late blossoming trait with good market qualities. Breeding of new varieties that shall have this combination has been sought in several projects in the United States and abroad (2, 9). The advantage to be gained from late blossoming has been demonstrated frequently, most notably in progenies of apples raised by Chandler at the Missouri Agricultural Experiment Station from late blossoming varieties; following the memorable Easter freeze of 1921 many of these seedlings bore heavy crops. Perhaps because the advantage of late blossoming appears obvious, only few writers (4) have attempted definite evaluation of this trait. In fact the advantage has been qualified (8) and questioned directly (7) or by inference (10), partly on account of alleged lack of resistance in these varieties to very late frosts and partly because of a belief in some quarters that resistance increases with transition from flower to fruit. The objection that late blossoming varieties of apples are unproductive has been founded to some extent upon unconscious failure to provide them with effective pollenizers (3). There seems to be no statement, even approximate, as to whether any advantage conferred by late blossoming is confined to the pre-blossom period or extends into the actual flowering season.

Study of late blossoming is further complicated by diversities of classification of varieties in this respect. Collation of published lists arranging varieties in sequence of blooming reveals some surprising differences, even from year to year on the same trees. Some of these differences may be due to site inequalities and some to the rootstocks on which the trees are grown (5). Equally great diversity in records can arise from failure to consider the type of growth which bears the blossom; the interval between unfolding of blossoms on spurs and of those borne laterally on the same tree is enough to affect its placing in a sequence (1) if the record fails to compare like growths.

Frosts at Glenn Dale, Md. in the spring of 1943 permitted comparison of some late blossoming varieties in terms of standard varieties and evaluation of their susceptibility to early and to late frosts. On April 11 injury, probably occasioned by a temperature of 18 degrees F on April 5, was observed on some very early blossoming varieties from North Africa and Manchuria; petals were open and uninjured, but pistils and stamens were killed and crop loss was complete. On April 16 the temperature dropped again to 18 degrees F. Examination on April 18, when Delicious blossoms were just separating in the cluster, revealed virtually complete crop destruction in that variety, through killing of the pistils; loss in Grimes was estimated at that time as 40 per cent. Complete loss of crop prevailed in many crab-apples, Gravenstein and many Russian varieties. Aside from a temperature of 28 degrees F on April 23, no other dangerous frost occurred until May 2, when the thermometer registered 25 degrees F. This distribution of injurious temperatures permitted, for a few days following May 2, classification of injury into early and late. A record of some of the counts made before and after May 2 is presented in Table I; these counts, except as specifically noted, were taken in the portion of the orchard included between two rows (6 and 13) in which the two Rome Beauty trees stand. Since these two trees showed little difference in injury, site differences are presumed to have exerted little influence on frost incidence under existing conditions. All trees had been grown in the nursery at Glenn Dale and worked on standard commercial seedlings.

It was not always possible, in the second examination, to determine accurately the number of blossoms killed in the tight cluster stage by the earlier freezes; in these cases record was made only of late injury

TABLE I—FROST INJURY TO CERTAIN APPLE VARIETIES AT GLENN DALE, MARYLAND, IN SPRING OF 1943

P. I. Number	Variety	Blossom Period	Flowers Examined (No)	Dead May 1 (Per Cent)	Killed May 2 (Per Cent)	Final Survival (Per Cent)
	Delicious	3	350	98.0	—	—
	Jonathan	3	264	91.6	59.0	4.3
	Stayman	3	212	92.0	—	—
	Grimes	3	307	59.2	90.4	3.9
	Rome (Row 6)	4	277	57.0	12.8	37.5
	Rome (Row 13)	4	305	57.0	17.3	35.6
	Northern Spy (Row 3)	4	337	14.2	—	—
	Northern Spy (Row 12)	4	165	20.7	36.4	50.5
76751	Bonne Hoture	(4)	164	5.5	—	—
	Bonne Hoture		223	—	19.3	76.3
125731	Reichelsheimer Weinapfel	(3)	207	12.6	68.0	28.0
105156	Daru	(4)	206	17.0	—	—
102548	Grugno di Cane	(3)	243	20.2	—	—
	Grugno di Cane		190	—	55.8	35.3
123735	Cremière	(4)	202	21.0	10.7	70.3
127946	Castle Major	(4)	209	22.0	74.1	20.1
104719	Claygate Pearmain	2	271	22.5	85.7	11.1
125563	Reinette Clochard	(4)	135	25.2	—	—
	Reinette Clochard		82	—	51.2	36.4
125721	Reinette Thouin	(4)	235	25.5	14.9	63.4
105499	Calvilla amarilla de Quendo	(4)	260	27.3	—	—
	Calvilla amarilla de Quendo		289	32.2	12.8	59.2
55223	Lane's Prince Albert	3	215	39.5	—	—
	Lane's Prince Albert		228	—	58.8	29.9
103442	Antonovka	2	248	40.3	—	—
	Antonovka		216	—	54.6	27.1
131820	Colapuy	(4)	317	43.8	9.0	51.1
128330	Rh. Bohnapfel Findling	(4)	269	44.2	39.3	33.8
119216	Pippin Kitaika	(3)	318	44.7	44.9	30.5
55214	Cousinotte rouge d'hiver	(3)	228	45.2	—	—
	Cousinotte rouge d'hiver		177	—	45.2	30.0
55222	Winter Gold Pearmain	3	418	56.0	70.1	13.2
104027	Courtpendu royal	4	167	59.0	6.0	37.7
104716	Annie Elizabeth	4	203	64.0	—	—
104731	Margil	2	221	65.6	—	—
104721	Cutler Grieve	(4)	209	65.6	79.6	7.0
104034	Reinette dorée	4	253	67.2	—	—
131508	Malinowa Oberlandzka	(3)	312	67.3	34.3	21.5
104995	Pippin Shafran	(2)	520	69.4	64.7	11.0
104807	Pederstrup	(2)	388	70.1	67.2	9.8
104732	Mrs. Phillimore	4	242	77.3	—	—
104733	Orleans Reinette	3	216	81.5	—	—
102140	Gladstone	4	171	83.0	—	—
104030	Golden Noble	4	224	86.6	—	—
104031	Jakob Lebel	2	166	98.2	—	—

and uninjured blossoms; the first count was used for early injury and the percentage of survival was calculated. Varieties thus treated are indicated by the use of two lines in the table. Early and late counts were made on the same trees.

The percentage of injury sustained on May 2 is calculated in terms of flowers surviving the earlier freezes; "final survival" is calculated on the basis of the initial total examined. Obviously, therefore, the percentages will not total 100. The blossoming periods indicated, "1" denoting earliest and "4" denoting latest, are, so far as possible, reproduced from Kobel (6), though experience at Glenn Dale would indicate need of slight shifts in a few cases; those supplied from other sources or from observations at Glenn Dale are enclosed in parentheses.

If the full records, embracing scores of earlier blossoming varieties in which crop loss was virtually complete, could be presented, the value of late blossoming would appear in a most impressive manner. A random selection of records from another orchard — not reported in the table — in which injury to Rome Beauty aggregated 44.2 per cent, disclosed two varieties with survival over 25 per cent, six with survival between 11 and 25 per cent and 20 with less than 10 per cent, mostly lower than 5 per cent; in at least 20 of the 28 varieties the crop was practically destroyed. This advantage of late blossoming is not vitiated by the vagaries revealed by the data presented in the table. Nevertheless these are not to be ignored. It is obvious that frost resistance has a general, but not a strict, relationship to order of blossoming. Northern Spy, though late in flowering, has been consistently earlier than Rome Beauty, but suffered less from the early freezes. The resistance shown by Antonovka blossoms appears inconsistent with their comparative earliness.

If it were assumed that resistance decreases steadily with advancement of the blossom and that there are no differences between varieties at equal stages, then it would be expected that the varieties suffering the most heavy losses in the early freezes would also suffer most in the later freezes. For ready scrutiny of this concept, the data presented for the foreign varieties in the table are arranged in a sequence based on early injury. It is manifest that this sequence does not prevail at all strongly in the injuries from the late freeze. The records of the six varieties showing lowest early injury include late injuries of 68.0 per cent and 74.1 per cent; the record of Courtpendu royal shows early injury of 59 per cent and late injury of 6 per cent. A striking example of divergence in extent of late injury is afforded by Cremière and Castle Major, in which the early injuries were almost identical, but the late injuries were 10.7 per cent and 74.1 per cent respectively.

Late blossoming seems to have been somewhat more closely related to escape from late, rather than early, injury. This is suggested by the inclusion in the six varieties (with complete records) least injured by the early freezes, of three varieties blossoming late, two in late midseason and one in early midseason; the six varieties least injured by the freeze of May 2 were all in the late blossoming group.

Explanation of the failure of late injury to correspond with early injury may lie in several possibilities: (a) fluctuation in hardiness as the blossom develops. Nothing observed in this study supports this view so far as any single variety is concerned. Its popularity may be due to failure to appreciate the check in growth of the injured blossom, which in a very short time is surpassed in size by an uninjured blossom, which then appears more advanced; (b) early injury may spare only the very late blossoms or it may leave some rather advanced blossoms uninjured; a second freeze may then levy greater toll where the initial injury was less. This view implies varietal differences in hardiness at the same early stage; (c) the spread between the early blossom and the last blossom in a cluster may be greater in some varieties than in others. This clearly accounts for the low late injury in Courtpendu royal, shown in the table; (d) Morphological (and chemical) differences, accentuating as the blossoms unfold, may make the increase in tenderness more pronounced in some varieties than in others. Some plausibility attaches to this view because of differences noted in incidence of injury; in Grugno di Cane and Cousinotte rouge d'hiver, for example, many, if not most, of the late injuries involved solely the ovules; in most varieties the anthers were uninjured when pistils and ovaries were killed, while in Castle Major there were no intermediate cases, a blossom surviving or sustaining injury in ovules, pistils and anthers. When blossoms are fully open, varieties with larger coarser flowers seem more tender than those with smaller flowers and smaller organs, but there are exceptions to this generalization.

Whatever the cause, the fact is obvious. Without the freeze on May 2, this report on frost-resistance would have differed markedly.

The considerations here presented seem to warrant: (a) some assumption of sustained frost survival accompanying late blossoming; (b) some caution against too complete reliance on this assumption in selecting parents for breeding; and (c) care in acceptance of records from a single frost for variety evaluation, unless the frost is comprehensive in its scope.

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Hand Pollination Studies on the Cherimoya

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HAND pollination of the cherimoya (*Annona cherimola*) has been demonstrated to be an effective and practical means of increasing fruit-set and improving fruit quality. The practice has been employed in Egypt (1) on a commercial basis for several years past. Beneficial results have also been obtained in California (2) where it has been shown that the fruit-set may be 60 per cent or more from the flowers pollinated by hand while similar control flowers set fruit to the extent of about 2 per cent. A higher percentage of perfectly shaped fruits and fewer "runts" results from hand pollination as compared with natural sets. Also, the inherent seediness of the fruit is not increased by this practice.

METHODS AND MATERIALS

The method employed which has proved to be the most satisfactory in southern California is as follows. Flowers are gathered for their pollen in the afternoon. Only flowers which are just starting to open are selected, at which stage the stigmas are glistening and sticky, but the pollen is not yet shed. They are placed in paper sacks together with pieces of moist paper towel to maintain the humidity. By the next morning the petals are very loose and somewhat reflexed and the pollen is shedding. The pollen is then shaken into a small glass vial which is kept stoppered with another piece of moist towel. By means of a small, blunt camel's-hair brush the pollen is then applied to freshly opened flowers in which the stigmas are sticky and receptive. Precautions are taken to maintain a humid atmosphere over the pollen during the entire procedure.

The experimental materials consisted of trees in the variety collection in the university orchard and in commercial plantings in several localities in southern California.

RESULTS

Hand pollination has been found to be effective in causing fruit-set on trees 2 years of age and older growing in the orchard or in wooden tubs. Flowers borne on old, gray wood or those borne on new, green branches have set fruit equally well. Flower buds which frequently arise along the trunk or a main limb have also set fruit if properly pollinated.

An important factor found to influence fruit-set is the tree condition at time of pollination. Trees of some cherimoya varieties mature their flowers before the leaves have emerged and expanded fully. In other varieties the leaves appear before or simultaneously with the flowers. It has been shown that fruit does not set until the leaves have fully developed and are functional although other conditions such as adequate pollination and ideal environment are favorable for setting. The results of a typical observation are given in Table I. The Booth and Carter trees both started to bloom about June 1st at which time the former trees were almost fully in leaf. The Carter trees did not leaf out until the last of June, consequently they set no fruit until that time. Good fruit set was obtained any time after full leaf development.

TABLE I—Relation of Leaf Development to Set of Fruit

Date Pollinated	Variety			
	Booth		Carter	
	Number of Flowers Pollinated	Per Cent Set	Number of Flowers Pollinated	Per Cent Set
Jun 9	4	0.0*	21	0.0
Jun 11	1	100.0	6	0.0
Jun 13	11	63.5	18	0.0
Jun 16	10	90.0	10	0.0
Jun 24	11	100.0	15	0.0
Jul 1	10	100.0	31	19.4*
Jul 9	—	—	24	54.1
Jul 17	—	—	2	100.0
Jul 21	4	50.0	8	75.0

*Leaves fully developed.

That a long suspected tendency toward dichogamy exists in the cherimoya in California is demonstrated by the results obtained from pollinating freshly opened flowers before their pollen is shed (2). The flower opens only once, but has two stages of development. Upon opening it functions first as a pistillate structure and then later as a staminate organ. The results given in Table II indicate the ineffectiveness of pollinating old or second stage flowers which are shedding pollen, and illustrates the fact that dichogamy exists under California conditions.

TABLE II—Relation of Flower Development to Set of Fruit

Flower Stage	Number of Flowers Pollinated	Per Cent Set
First (pistillate)	23	91.2
Second (staminate)	21	19.0

Discussion

The cherimoya fruit is a syncarpium composed of many individual pistils which become fused during development to form a solid mass. Each pistil must be pollinated to produce the seed within it and subsequently to develop the ovary wall. Thus if only a few seeds develop the fruit is small and often irregular in shape. In order to insure a large, well shaped fruit all or most of the pistils must be pollinated. Under conditions of natural pollination adequate pollen transfer is often limited. Insect visitors have been observed to be scarce in California.

Under the more humid coastal conditions in southern California hand pollination has proved very effective. In more arid, inland environments, however, this practice sometimes fails to set fruits when the temperature is high (90 to 95 degrees F) and the humidity low (25 to 30 per cent). Pollination under more favorable, normal conditions (80 degrees F, 70 to 80 per cent relative humidity) in these inland districts, however, results in a high percentage of set. Desiccation of the pollen is probably the limiting factor in successful pollination under hot and dry conditions. This is suggested by the practice in Egypt of inserting a drop of water in the flower at the time of pollen transfer which insures high humidity for the germinating pollen and results in better set (1).

Storage of pollen has not been found feasible although in some trials it has been kept in a humid atmosphere for 2 days when it still proved viable and effective in pollination. Other pollen allowed to dry in the room was worthless after one day of storage. A 4 per cent set only resulted from pollen kept at 15 degrees F and 50 per cent relative humidity for 10 days. These observations point to the probable susceptibility of the pollen to desiccation and its failure to germinate under arid conditions.

Hand pollination as a commercial orchard operation has proven to be entirely practicable and has been employed to some extent by several growers in California with good results. Such practice allows for a more regular distribution of the crop throughout the season if the trees are systematically pollinated every few days. If carried on during the height of bloom in a mature orchard it has been shown that unskilled workers require about 10.5 man-hours to hand pollinate about 1500 flowers. Assuming a 50 per cent set from this practice, although a greater set generally results, the cost of hand pollination is less than one cent per fruit.

Summary and Conclusions

It may be concluded that hand pollination of the cherimoya is a practical and effective means for increasing the crop set, and for improving fruit size and quality. A tendency toward dichogamy is shown to exist in this plant under southern California conditions. This is probably one of the major causes for the lack of natural pollination and resultant low yield. The important factors upon which the success of hand pollination depends are the conditions of the pollen used, the stage of maturity of the flower which is pollinated and the tree condition at time of pollination.

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Studies of Plum Pollen, Its Appearance and Germination

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ABSTRACT

The complete paper will appear in the *Journal of Agricultural Research*, Volume 67, 1943.

THE percentages of normal pollen and also the pollen germination rates of several plum varieties have been investigated in three different seasons. The plums studied have included most of those commonly grown in the Southwest as well as many little grown varieties and a number of botanical species.

In 1940 the amounts of normal pollen were studied in 37, in 1941 in 59, and in 1942 in 23 plum varieties or Prunus species. Grains were counted as normal when they were plump, regular appearing and were filled with cytoplasm that stained to some extent in acetic acid-iodine mounts. Correlation coefficients indicate a strong tendency for the percentage of normal pollen in a given variety to be consistent from year to year. Other environmental factors, such as the location of trees from which pollen was secured, also had no significant effect, on the whole, on the percentage of normal pollen within a variety.

Several factors affecting adequateness of the pollen sample were investigated. Significant flower to flower variation, with respect to aborted pollen, was found to occur on the same tree of Surprise plum. This, coupled with sample checks on different sized collections of pollen, show that if a relatively small tree or varietal sample is to prove reliable that it must be taken from a sufficiently large and well-mixed pollen collection. It has seemed safe to conclude that 1000-grain samples from such collections are adequate for reliability. This was the size of sample used in most of the present work. The data show, however, that much larger samples from small collections of flowers exhibit significant variation.

Pollen of 21 varieties in 1941 and of 18 in 1942 were germinated on nutrient agar. There was a significant year to year correlation for germination of the pollen of varieties used both years. For all varieties studied the proportions of germinating pollen were lower than those of normal appearing pollen. When all varieties studied in a single year were considered together, however, there were highly significant correlations between percentages of normal pollen and actual germination in each year. Individual exceptions occurred. The germination tests in general substantiate the conclusions based on results of the abortion studies.

A number of the varieties studied are hybrids between two or more Prunus species. Both the germination and the abortion studies make it seem likely that the degree of hybridity is responsible for the general level of pollen sterility, and hence that this level is fundamentally determined by the genotype of the variety.

Thinning Apples and Peaches with Blossom-Removal Sprays

By L. P. BATJER and H. H. MOON, *U. S. Plant Industry Station, Beltsville, Md.*

PREVIOUS results with caustic bloom sprays (3, 4) showed tar oil distillate and di-nitro-ortho-cyclo-hexyl-phenol to be very effective in reducing fruit set on a number of apple varieties when thoroughly applied during the cluster bud stage at one-third to one-half dormant-spray strength. These sprays seem to have their greatest value in reducing the current crop sufficiently to change the bearing year of biennial producing trees. It was also found that the crop could be almost completely eliminated by making two applications, the second being applied at the pink stage of blossom development.

Experiments conducted in both the East and the Northwest with these two materials have shown definite differences in varietal responses. Thus, with Yellow Transparent, no reduction in ultimate fruit set was obtained from using either material. Because of the heavy set during the "on" year of this biennial variety, size of fruit is unsatisfactory under most conditions. It is therefore necessary to resort to expensive hand thinning, and the prices paid in the case of this variety frequently have failed to justify such a costly operation. The recent extensive studies by MacDaniels and Hoffman (2) and Hoffman (1) have indicated that Elgetol, a sodium salt of dinitrocresol, used as a blossom-removal spray on apples gives considerable promise under New York conditions as a practical means of thinning apples, particularly the Wealthy variety. The present experiments were performed in order to determine the effect of Elgetol used as a blossom spray on the fruit set of Yellow Transparent apples and several varieties of peaches under conditions in Central Atlantic States.

YELLOW TRANSPARENT EXPERIMENT

The 12-year-old trees used in this experiment were growing in a heavy bluegrass sod near Martinsburg, West Virginia; they had an abundance of buds but were slightly below average in vigor. Table I gives the results obtained when various strengths of Elgetol spray were used at different stages of blossom development. The trees were given an extremely heavy "drench" application, using 6-nozzle brooms with 500 pounds pressure, operated from both the ground and the top of the spray machine. The spray for all treatments was applied under ideal conditions and every effort was made to hit all blossoms.

The entire crop of fruit was harvested in a single picking on June 29, 64 days after full bloom. At least two "spot pickings" for size, extending 65 to 80 days after full bloom, is the usual practice with Yellow Transparent in this fruit section. However, it was necessary for the fruit grower in this instance to handle the crop in one picking as indicated above.

All spray treatments resulted in marked reduction of fruit set and yield. The data in Table I clearly show that Elgetol, with the concen-

TABLE I—EFFECT OF ELGETOL SPRAYS APPLIED DURING BLOOMING PERIOD ON SET, SIZE, AND YIELD OF YELLOW TRANSPARENT APPLES

No of Trees	Spray Treatment* Strength and Date (Per Cent)	Open Blossoms (Approx Per Cent)	Mean No.† of Fruits Per 100 Blossoming Spurs	Mean No. of Bu Per Tree	Mean No. of Fruits Per Bu	Size of Fruits—(Percentage)				Spray Injury to Foliage
						Under 2 Inches	2 to 2¼ Inches	2¼ to 2½ Inches	Above 2½ Inches	
9	0.4 Apr 22	None‡	20±3.3	4.0	280±17	26	30	30	14	Medium
7	0.3 Apr 24	30	9±1.3	2.1	298±33	25	29	32	14	Medium
9§	0.3 Apr 24 0.15 Apr 25	30 95	4±0.8	1.0	326±28	29	27	31	13	Severe
5	0.3 Apr 25	90	13±2.9	3.7	257±12	19	28	33	20	Slight
9	0.2 Apr 25	90	22±3.3	3.8	237±12	12	20	40	28	None
Check	—	—	64±6.0	7.1	403±19	63	28	9	0	—

*Temperatures prevailing at time of spray applications: April 22, 55 degrees F; April 24, 70 degrees F; April 25, 77 degrees F. Range of daily maximum and of daily minimum temperature from April 22 to April 26, inclusive was 70 to 86 degrees F, and 40 to 47 degrees F, respectively.

†Data obtained from fruit set record (made after June drop) based on an average of 1200 blossoming spurs per tree located on four typical branches.

‡Blossoms in advanced pink stage with center blossom in medium balloon stage.

§These trees received two applications.

tration used and applied at prebloom and partial full-bloom stages, was effective in reducing the percentage of blossoms setting fruit. There is a striking point of difference in this respect between these results and those obtained by MacDaniels and Hoffman (2), in that fruit set and yield were reduced under the conditions of this experiment when sprays were applied to unopened blossoms. Many of the unopened blossoms sprayed with .3 and .4 per cent concentration either failed to open or the flower pedicels were so severely injured at the base that they soon abscised.

Generally, greater spray injury to foliage and growing points resulted when these sprays were applied prior to full bloom. As may be seen in the last column of Table I, different degrees of spray injury to the leaves resulted from the various treatments. By "slight" injury is meant a moderate amount of marginal burning on primary leaves and a slight crinkling and mottling of the later leaves, but no leaf buds killed. Three weeks after treatment the leaves were somewhat lighter green than normal, but by harvest time the foliage system appeared normal. "Medium" injury was characterized by severe killing of primary leaves, crinkling and mottling with some burn on later leaves, and a moderate amount of leaf-bud killing, together with the death of some spurs on the weaker limbs. At harvest time the foliage of these trees was somewhat sparse and light green. "Severe" injury refers to trees that had severe killing of primary leaves, crinkling and mottling of later leaves, and a moderate amount of marginal burning. Leaf-bud and spur killing were severe, particularly on the lower limbs. At harvest time the foliage of these trees had a definitely sparse appearance. The leaves were light green and noticeably smaller.

For the trees used in this experiment, about 4 bushels would be considered a satisfactory commercial crop, from the standpoint of yield and size of fruits. The trees receiving either the .3 per cent or the .2 per cent spray treatments applied during full bloom were satisfactory from the standpoint of fruit set, yield, size of fruit, and amount of spray injury. The .4 per cent prebloom spray resulted in a favorable yield, but the greater amount of injury was doubtless responsible for the smaller size. The effect of spray injury on fruit size is strikingly demonstrated in the trees that received a repeat spray. The spray injury was severe on these trees, and even though fruit set was reduced to 4 per cent and yield to 1 bushel, fruit size was smaller than in any treatment other than the checks.

In 1943 blossom records were obtained on these trees by making careful estimates at bloom time. The check trees failed to blossom except in the case of 15 to 20 blossom clusters occurring on small limbs on each of two trees. Bloom on the sprayed trees varied from a scattering over the entire tree to a concentration of bloom occurring mainly in the upper portions, or in some cases confined to several scattered limbs. With this variety a bloom of 15 to 20 per cent of the growing points is normally sufficient for a full crop. Trees with the greatest reduction in set generally came back with the most bloom. Nevertheless, there were a number of exceptions, particularly in instances where tree vigor was above the average for the block. Of the 14 trees receiving the .2 and .3 per cent spray treatments applied during full bloom, four trees had a 1943 bloom of over 10 per cent; five trees varied from 2.5 to 10 per cent; and five trees had less than 1 per cent.

PEACH EXPERIMENT

Ten-year-old Golden Jubilee, South Haven, and Elberta peach trees in good commercial vigor, growing at Beltsville, Maryland, were used

TABLE II—EFFECT OF ELGETOL SPRAYS APPLIED DURING BLOSSOMING PERIOD ON SET, SIZE, AND YIELD OF PEACHES

No. of Trees	Treatment*— Spray Strength (Per Cent) and Date	Open Blossoms (Per Cent)	Fruit† Set (Per Cent)	Mean No. Bu Per Tree	Mean No. Fruits Per Bu	Spray Injury
			Golden Jubilee			
3	Check—Unthinned	—	18.7±3.9	10.0	189± 2	———
3	Check—Hand thinned	—	16.0±1.6	6.1	166± 7	———
3	0.4 Apr 15	95	2.0±1.1	0.9	107± 4	None
3	0.2 Apr 15	95	6.1±1.3	4.4	124± 4	None
	0.1 Apr 15	95	7.1±1.4	3.8	123± 6	None
			South Haven			
2	Check—Unthinned	—	30.7±5.1	8.1	198± 4	———
2	Check—Hand thinned	—	28.7±5.4	6.0	153± 4	———
4	0.2 Apr 8	0	20.1±2.6	6.1	155±15	Slight
4	0.4 Apr 8	0	12.1±1.7	5.1	131± 6	Severe
3	0.2 Apr 15	70	13.8±2.0	5.8	139± 4	None
			Elberta			
2	Check-Unthinned	—	28.0±5.9	11.3	173±19	———
2	Check—Hand thinned	—	28.5±3.1	6.1	125± 1	———
2	0.1 Apr 11	95	21.3±0.4	5.8	130±13	None
4	0.2 Apr 11	95	13.0±1.4	6.5	100± 7	None
2	0.4 Apr 11	95	4.5±2.9	2.7	93± 2	Medium
4	0.2 Apr 8	68	6.7±2.5	2.7	98± 6	Slight
4	0.4 Apr 8	70	2.2±1.0	1.3	77± 5	Severe

*Temperatures prevailing at time of spray applications: April 8, 58 degrees F; April 11, 50 degrees F; April 15, 70 degrees F. Range of daily maximum and of daily minimum temperatures from April 8 to April 16, inclusive, was 42 to 80 degrees F and 32 to 50 degrees F, respectively.

†Data obtained from fruit set record (made after last drop) based on an average of 900 blossoms per tree located on three typical branches.

in this experiment. Elgetol sprays were applied in the concentrations and on the dates indicated in Table II. These data suggest about the same range of effective concentrations of Elgetol with peaches as with apples. With the trees used in this experiment a yield of about 6 bushels of fruit was considered a desirable crop. With the Elberta variety, sprays of .1 and .2 per cent concentration applied in full bloom resulted in a yield of about this amount, but with Golden Jubilee the same two treatments were followed by yields of 4.4 and 3.8 bushels, respectively. With the Elberta and South Haven varieties, the .4 per cent concentration resulted in rather serious injury, particularly to the leaf buds and 1-year twigs on the lower branches. In the case of Elberta this injury with the .4 per cent spray was definitely less when the spray was applied at full bloom. However, in all cases where severe injury resulted from spray treatments, the trees made a rapid recovery and by June 1, with the exception of a few lower limbs, the foliage was large, dense, and dark green.

Discussion

Due to the limited number of trees available and the exploratory nature of the treatments, no definite conclusions can safely be drawn from these results. The results of these and of other experiments (1, 2, 3, 4) emphasize that responses obtained with blossom sprays may in a large measure be influenced by such factors as variety, vigor, blossom development, weather conditions, and possibly other factors not yet considered. An outstanding characteristic of these sprays, both on apples and peaches, was the much greater reduction in fruit set on the lower limbs as compared with the branches in the upper half of the tree. While more complete spray coverage on the lower branches was possibly a contributing factor, it is felt that the chief reason for the difference was the greater susceptibility to injury of the blossom on the relatively less vigorous growth. Considerable variability in response among trees of a given treatment (note large standard errors in tables) in these experiments and others by the authors (3, 4) raises a question as to the commercial feasibility of blossom sprays as a substitute for hand thinning. In this connection, it will suffice to say that commercial tests thus far have been too limited to justify any general recommendation. Nevertheless, where the cost of thinning certain varieties is prohibitive and under conditions of critical labor shortage, blossom-thinning sprays seem to have sufficient promise to merit further experimental study.

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Some Results of Thinning Certain Apple Varieties at Bloom Time with a Caustic Spray

By M. B. Hoffman and J. D. VanGeluwe, *Cornell University, Ithaca, N. Y.*

IN New York orchards it is characteristic of some apple varieties to set more heavily than others. The heavy setting of such varieties as Yellow Transparent, Early McIntosh, Wealthy and Baldwin is associated with and probably largely responsible for the distinct biennial bearing habit of the trees. During the "on-years" hand thinning of such varieties is usually necessary to produce fruit of commercial size. While hand thinning will improve the size and quality of the immediate crop it is not practical to accomplish the thinning early enough to influence annual bearing.

Preliminary work has indicated that there is a possibility of thinning some varieties with a caustic spray at bloom time. MacDaniels and Hildebrand (1) showed that a dilute solution (0.1 or 0.2 per cent) of the sodium salt of dinitro-cresol (Elgetol) was toxic to pollen. This material has been used as a bloom spray on Wealthy for the purpose of reducing the set (2, 3). In these tests the best control over the degree of thinning was obtained by applying the toxicant just as the trees reached approximately full bloom. Some of the treatments have resulted in a second successive crop (4).

Similar tests were repeated on Wealthy and several other varieties in 1942. Most of the applications were made just as the trees reached full bloom or as soon as it was possible to apply the material after the lateral flowers of the spurs had opened. The object in such timing was an attempt to prevent the set of all the lateral flowers of each spur and to determine the amount of crop development possible from the center flowers which had opened earlier.

All blossoming spurs on two representative unit branches of each tree were recorded at bloom time. The fruiting spurs and the total fruits on these branches were counted after the June drop. The per cent of blossoming spurs bearing fruit and the average number of fruits per 100 blossoming spurs were calculated. Expressed in this way, a tree should carry a minimum of about 20 apples per 100 blossoming spurs to be considered as having a commercial crop. When the thinning is done as early as the bloom period, many varieties will develop commercial size with a set of 40 to 50 apples per 100 blossoming spurs. This amount of set, however, might not permit the production of commercial crops annually.

The data in Table I show the effect of these bloom sprays on the set of fruit by eight different varieties. The set was reduced heavily in the case of Northwestern Greening, Cortland and Delicious. The reduction was somewhat in proportion to the concentration of the spray but even the weaker concentration of 1 pint per 100 gallons removed more fruit than was desirable. The Northwestern Greening and Cortland trees were vigorous. These varieties were sprayed immediately on reaching full bloom. The petals adhered tightly on all flowers. The

TABLE I—EFFECT OF ELGETOL APPLIED AT BLOSSOM TIME ON THE SET OF CERTAIN VARIETIES OF APPLES

Variety and Orchard	Vigor	Stage Bloom	Number Trees	Per Cent Concentration of Spray	Number Blossoming Spurs	Per Cent Blossoming Spurs with Fruit	No. Fruits Per 100 Blossoming Spurs	Approximate Per Cent Fruiting Spurs Bearing Clusters
Northwestern Greening Orchard 1	Good	1st day Full	2	Check	219	36.0	38	2.0
			3	0.125	351	11.0	11	0.0
			3	0.25	352	1.0	1	0.0
Cortland Orchard 2	Good	1st day Full	3	Check	216	30.4	34	3.6
			4	0.125	348	7.0	7	0.0
			3	0.25	195	2.0	2	0.0
Delicious Orchard 3	Low	2nd day Full	3	Check	321	32.5	35	2.5
			4	0.125	321	8.0	8	0.0
			4	0.25	371	0.0	0	0.0
Stark Orchard 4	Med.	2nd day Full	2	Check	204	54.0	60	6.0
			3	0.125	390	25.0	25	0.0
			3	0.25	360	9.0	9	0.0
McIntosh Orchard 5	Good	1st day Full	2	Check	184	82.0	98	16.0
			2	0.125	142	74.0	76	1.5
			3	0.25	326	31.0	32	1.0
Wealthy Orchard 6	Low	1st day Full	4	Check	382	43.4	63	19.6
			3	0.125	423	23.1	27	3.9
			3	0.25	416	5.0	5	0.0
Wealthy Orchard 7	Good	2nd day Full	3	Check	378	54.6	74	19.4
			6	0.125	698	33.5	45	11.5
			6	0.25	902	33.0	43	10.0
Wealthy Orchard 8	Good	1st day Full	5	Check	1,223	74.0	109	35.0
			5	0.2	1,402	38.6	40	1.4
Baldwin Orchard 9	Good	1st day Full	2	Check	374	44.3	72	27.7
			3	0.125	311	46.4	51	4.6
			2	0.25	218	31.5	32	0.5
Baldwin Orchard 10	Good	1st day Full	3	Check	551	81.8	133	51.2
			4	0.125	443	60.4	67	6.6
			4	0.25	497	47.5	48	0.5
Rome Beauty Orchard 11	Good	1st day Full	2	Check	182	52.0	57	5.0
			3	0.125	263	34.0	35	1.0
			3	0.25	279	15.0	15	0.0

Delicious trees were low in vigor and in need of a detailed pruning. When the spray was applied the trees had been in full bloom for 24 to 30 hours during which time good pollination weather prevailed. The spray knocked off many petals.

The Stark trees, located on the same farm as the Delicious, possessed somewhat more vigor. Blossom development of the Stark was about the same as that of the Delicious at the time the spray was applied. The stronger concentration of the spray reduced the set of fruit on these Stark trees too much but a satisfactory degree of thinning was accomplished with the weaker concentration and a good commercial crop developed.

In Orchard 5 the McIntosh were interplanted with Cortland and Wealthy. These trees were very vigorous as indicated by the heavy set of the checks. Most lateral flowers of the spurs had been open 6 to 8 hours when the spray was applied. Some thinning was accomplished with both concentrations. The fruit on the trees receiving the stronger concentration of spray developed to greater size than is desirable for market purposes. Normally, McIntosh does not set so heavily as did these particular trees and since the moderate sizes are in greater demand there is less need for thinning this variety than some others.

Wealthy trees were sprayed in three orchards. Because of shallow soil the trees in Orchard 6 were small for their age, however they had been well fertilized and the foliage appeared healthy. Under such conditions the stronger concentration of 1 quart of toxicant per 100 gallons caused too great a reduction in set. The weaker concentration of 1 pint per 100 gallons thinned the crop satisfactorily. In addition to these record trees there were 200 other Wealthy trees in this block. All of these were sprayed at the same time by the owner with a concentration of 1 pint per 100 gallons. The block produced a good commercial crop of 3-inch apples in 1942 without hand thinning and all trees except the four which served as checks blossomed heavily in 1943 when the bloom treatment was again used for thinning.

The Wealthy in Orchard 7 were sprayed on the second day of full bloom, which seemed to have been about 24 hours too late to accomplish the desired thinning with the concentrations of spray used. Some of the lateral flowers set which accounted for about 10 per cent of the fruiting spurs producing doubles or triples. A spray concentration of 0.2 per cent was used on the Wealthy trees in Orchard 8 on the first day of full bloom. This treatment caused a satisfactory reduction in set and the fruit developed to a minimum size of 2¾ inches without hand thinning. The check trees set very heavy and produced no marketable fruit. While the Wealthy trees in both Orchards 7 and 8 were considered vigorous those in Orchard 8 had been more heavily fertilized with nitrogen which would account for the heavy setting of the checks.

The Baldwin trees in Orchards 9 and 10 were vigorous and set heavy crops; under these conditions the stronger concentration of the spray gave the best results. In the case of the Rome Beauty in Orchard 11, the stronger concentration may have reduced the set more than desirable but this was largely compensated for by an increase in fruit size.

Because of other work and a scarcity of help on the various fruit farms it was impossible to get final records of yield and fruit size on all these tests. This information was obtained only for the Baldwin in Orchard 9 and the Rome Beauty in Orchard 11. These data are summarized in Table II.

TABLE II—EFFECT OF ELGETOL APPLIED AT FULL BLOOM ON THE SIZE AND YIELD OF APPLES

Variety and Orchard	No. Trees	Concentration of Spray	Average No. Bushels Per Tree	Average No. Fruits Per Bushel*
Baldwin Orchard 9	2	Check	43.2	135
	3	0.125	42.8	99
	2	0.25	47.5	84
Rome Beauty Orchard 11	2	Check	12.0	124
	3	0.125	12.0	108
	3	0.25	11.0	93

*Based on a count of 5 bushels taken at random from each tree.

The bloom sprays had little or no effect on the total volume of fruit produced by these Baldwin and Rome Beauty trees. The number of apples to develop was reduced by the treatments but this was compensated for by a corresponding increase in size.

No stippen developed on the fruit of the treated Baldwin trees. This trouble might be encountered with Baldwin if a heavier thinning were accomplished.

One of the most noticeable effects of the early thinning was the improvement in the quality and quantity of color. This was especially true in the case of Baldwin. The fruits on those trees sprayed at bloom time developed color over more than two-thirds of the surface, and it was of a bright red type while fruit on the check trees developed not more than No. 1 grade red color of a dull, unattractive shade.

The foliage injury caused by the spray consisted of slight to moderate marginal burn of the young leaves. This injury does not seem to be of much importance and is hardly noticeable within 3 or 4 weeks after spraying, if the fruit set is reduced sufficiently to allow vigorous leaf growth to take place. When the application is made too late and excessive numbers of fruits develop, the growth of new foliage is held in check. The injury is then apparent all summer and under such circumstances may be of some consequence. The least foliage injury occurred when the spraying was done during the cooler parts of the day.

In these tests the spray was applied thoroughly so as to hit all flowers. No attempt was made to spray the trees from the under side. Some of the best results were obtained when the operator rode the tank and used a broom.

Spraying with Elgetol at bloom time to thin apples has more promise with some varieties than with others. The degree of self-fruitfulness of a particular variety in a given orchard seems to be an important factor. The results may vary also depending on the vigor of the trees, the stage of flower development at the time of spraying, the weather and the concentration of the spray.

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A Further Evaluation of Hormone Sprays[1]

By E. P. Christopher and S. A. Pieniazek, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

THE value of napthalene acetic acid both as the pure chemical or in commercial compounds as a means of delaying fruit drop has been reported by Murphy (4) and others (2, 3). Certain practical questions have arisen as to the effect of this practice upon total crop, color, quality, and storage condition. Some data seeking to answer these questions are presented.

A limited number of large McIntosh apple trees in the College orchard were available for the test. Certain of the trees were sprayed using one of the commercial hormone products at the manufacturer's recommended strength on September 7, 1942. The spray was timed in accordance with the recommendation of Murphy (5). A large power sprayer was used and about 15 gallons applied to each tree. Data were secured from three hormone treated trees and six unsprayed trees. Apples on three of the unsprayed trees were given additional support with adhesive tape to retain them on the tree during the test. Samples were taken before the hormone treatment and after 8 days, and stored under similar conditions.

One hundred apples were marked on opposite sides with India ink and measured with calipers accurate to 1/1000th of an inch. All fruit was harvested at the end of 8 days.

RESULTS

Size:—Earlier work with Rhode Island Greening (1) comparing different types of measurements and water displacement as a means of determining apple volume, indicated that comparable results could be secured by treating the fruit as a sphere. The volume of the McIntosh apples determined on this basis showed an average increase of 7.28 per cent during the 8 days involved in the test. These data are similar to those secured with Rhode Island Greening and indicate that a reasonable drop during the period of hormone treatment is compensated for by an increase in the size of the apples remaining on the tree.

Color:—As would be expected, fruit retained upon the tree for a longer period usually showed better color development. This amount will vary in importance from season to season but a few qualitative data are available. The fruits harvested at the beginning of the test showed an average of 68 per cent of the surface colored while those harvested later showed 79 per cent of the surface colored.

Eating Quality:—Quality is one of the most difficult things to measure. Taste preference by people not knowing the origin of any given fruit was used. Ten sets of fruit were tasted by 16 different people in mid-January. The fruits which had heen held on the tree the extra 8 days were preferred to others in practically every instance. No distinction was discernible between fruits held on by hormone spray or adhesive tape.

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[1] Contribution No. 649 of the Rhode Island Agricultural Experiment Station.

Storage Condition:—During the 1942–43 season very large quantities of McIntosh apples in commercial and farm storages developed mealy breakdown with attendant splitting. This difficulty has been ascribed by Plagge *et al.* (6) as due to overmaturity and to be favored by late harvest and delayed storage. The fruits used in this test were stored promptly and in no instance showed splitting. Apparently the improved size, color, and quality were secured without the fruit becoming overripe.

Pressure tests taken April 22, 1943 showed about the same average pressure for the hormone and adhesive-held fruits (5.22 and 5.23) but considerably higher pressure (6.25) for the earlier harvested untreated fruits.

An examination of 25 fruits from each lot for evidence of brown core showed that all 25 had moderate browning from the check lot, and 7 and 13 respectively had slight browning from the hormone and adhesive held lots. All of the fruit had been held for about a month in a storage at about 40 degrees F following very good storage conditions at 32 degrees F up to that time.

CONCLUSIONS

These limited data seem to indicate an increase in fruit size to offset moderate fruit drop, improved color, eating quality, and less brown core development in McIntosh apples held upon the trees longer by means of hormone sprays or mechanical means. Delaying harvest did not result in poorer keeping quality and the fruit was acceptable through mid April. These data further support the use of hormone sprays to reduce excessive drop and spread the labor load.

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Attempts to Influence Flower Bud Initiation in Apples by Chemical Growth Substances

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MANY experiments have shown a close association between the presence of a large quantity of carbohydrates in the tissues of fruit trees, and the initiation of flower primordia in the buds. A review of the literature on this subject, as well as considerable experimental evidence, has recently been given by Harley, *et al* (1).

A number of investigators have reported that the immediate effect of applying certain chemical growth-modifying compounds to plant tissues is to increase mobilization and accumulation of soluble organic constituents at the point of application. Thus Stuart (5) treated cuttings of kidney bean seedlings by immersing their bases in 0.01 per cent indoleacetic acid for 4 hours, and then set them in sand in a propagating frame for 100 hours. There was a marked increase in total nitrogen and total sugars in the treated stems, and a decrease in these materials in the leaves on these stems, as compared to check cuttings treated with water. Stuart and Marth (6) had previously reported a similar, though less pronounced, transfer of sugar to the stems of woody holly cuttings treated with indolebutyric acid. Mitchell (3) treated bean seedling stems at the first internode with 2 per cent naphthalene acetamide in lanolin and 2 per cent naphthalene acetic acid in lanolin. Both treatments resulted in swelling of the internode, the latter one causing tumor development within 3 to 4 days. Both treatments inhibited growth above point of treatment and resulted in accumulation of sugars and nitrogen compounds in the treated area. Mitchell and Hamner (4) found that treatment of young decapitated bean plants with very dilute indoleacetic acid in lanolin resulted in a markedly greater gain in total dry matter than occurred in similarly decapitated check plants, the leaf area in all plants being kept approximately equal by removing the axillary buds. These results indicate that photosynthesis was increased by the treatments with dilute indoleacetic acid.

In the treatments reviewed above, the mobilization of nitrogen compounds to the point of treatment appeared to be relatively greater than the mobilization of carbohydrates. Thus the ratio of carbohydrate to nitrogen in the tissues tended to decrease as a result of treatment.

Since such treatments have modified the nutritional conditions in treated tissues, it seemed desirable to determine if they would be effective in modifying the initiation of floral parts in buds of apple. An experiment was set up in the early summer of 1941 to obtain information on this point.

Winesap trees 8 years of age and bearing a heavy crop were used. All treatments were applied to spurs bearing one apple, and which had a secondary or new spur growth estimated to be not less than 2 nor more than 4 centimeters in length. All spurs within convenient working height which met these specifications were tagged in advance of applying treatments. These tags were then numbered in rotation from 1 to 6, the number of treatments to be applied. Thus each set of spurs receiving all the treatments was grouped on the tree. Since spurs were tagged and numbered before the order of treatment was determined, bias was eliminated in so far as possible. One set of trees received only two treatments, which accounts for the larger number of spurs reported for two treatments listed in Table I.

Treatments were applied May 26, 1941. According to earlier work (2) this was sufficiently early in the growing season that none of the buds would have flower parts actually present, but practically all could be influenced to initiate them. The treatments applied are shown in Table I.

The lanolin with incorporated chemicals was warmed sufficiently to be liquid, and was applied with small brushes. The whole stem of the new spur growth was covered, except in one experiment where the material was applied to the tip only.

None of the treatments resulted in increased flowering in the spring of 1942 (Table I). All lots of treated spurs, including those receiving lanolin only, showed a lesser percentage of flowering, based on number of spurs treated, than did the untreated checks. Because of the relatively low percentage of flowering on all spurs, data are inconclusive as to whether or not an actual relative decrease in flowering resulted from the treatments. No secondary thickening, such as has been observed as a result of applying napthalene acetamide to succulent bean stems (3) was observed as a result of any of the treatments.

TABLE I—FLOWER BUDS OF WINESAP APPLES FOLLOWING TREATMENT OF SPUR GROWTH WITH CHEMICAL GROWTH SUBSTANCES

Treatments Applied May 26, 1941	No. Trees Treated	Total Number Spurs Per Treatment	Fruits Dropped From Treated Spurs May 26 to Aug 11, 1941		Flower Buds April 17, 1942		No. Buds Dead
			Number	Per Cent	Number	Per Cent	
Check—no treatment	21	115	8	6.9	13	11.3	1
Lanolin only, entire spur shoot	27	155	10	6.4	6	3.9	6
50 parts per million naphthalene acetic acid in lanolin, entire spur shoot	27	155	18	11.6	4	2.6	12
50 parts per million naphthalene acetic acid in lanolin on tip of spur shoot	21	115	11	9.6	4	3.5	6
20 parts per million naphthalene acetic acid in 1 per cent oil, entire spur shoot	21	115	13	11.3	12	10.4	0
50 parts per million naphthalene acetamide, entire spur shoot	21	115	4	3.5	10	8.7	2

A similar series of treatments on 30 spurs each of Stark apples was applied May 19, 1941, and the new growth on the spurs was taken for chemical analyses August 1, 1941. The quantity of material proved inadequate for duplicate analyses, so the single analyses are not reported. There appeared to be no consistent differences in total organic nitrogen, starch, or total sugars as a result of any of the treatments of these woody spur growths.

DISCUSSION

Conditions favoring a relatively high carbohydrate condition in apple spurs, such as result from ringing branches early in the season, or from lack of a fruit crop on the tree, are generally highly favorable to the initiation of floral parts. Thus the mobilization of such materials to treated buds as a result of applications of growth modifying chemicals might be expected to influence the initiation of floral organs. It was assumed that penetration of the chemicals would occur, as similar methods of application will result in retardation of abscission of petioles and fruit stems of apples. If penetration actually occurred, the chemicals apparently were ineffective in modifying appreciably the growth condition of the spurs. Floral initiation was not greater following any of the treatments than in the untreated spurs. All treated groups formed fewer flower buds than the untreated checks, but because of the limited bloom that developed, the significance of this is questionable.

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The Levulose, Dextrose, and Sucrose Content of Fifteen Illinois Apple Varieties

By RICHARD V. LOTT, *University of Illinois, Urbana, Ill.*

IN studying the general subject of fruit development and quality the relative content of levulose, dextrose, and sucrose was determined for 15 apple varieties, most of which are grown commercially in Illinois.

Samples of each variety were collected at different stages of maturity, but only that stage of maturity which was found to be the optimum for the development of quality is reported here. A more detailed report will be made later concerning the behavior of these sugars during the development of the fruit. A representative sample of 25 fruits was used in each case. Longitudinal slices about ⅛-inch thick and extending to the center of the fruit were taken from each quarter of each fruit. These were cut into pieces approximately ¼-inch wide and 200 grams of this material dried to constant weight in a forced draft electric oven at 65 degrees C after an initial temperature of 90 degrees C for 30 minutes. The samples were ground to a fine powder in an Enterprise Mill, returned to the oven for an hour at 65 degrees C to remove most of the moisture absorbed during grinding, and drying completed in a desiccator over calcium chloride. The hygroscopic nature of the material made such finish drying necessary. The dry powder was stored in tightly-sealed, screw-cap, 5-ounce jars in the dark until analyzed.

Extraction, clearing, and deleading were accomplished on duplicate 1-gram samples by the method described by Lott (3) for peach flesh. Levulose and dextrose were determined by the method of Lothrop and Holmes (2) with the exceptions that reducing sugars were determined by the Shaffer-Somogyi method (5) as modified by Heinze and Murneek (1), and the quantity of each reagent was halved because of the relatively low sugar concentration of the solution. Sucrose was inverted as described by Lott (3) and total reducing power determined by the above method; this figure minus the reducing sugars was considered to be sucrose, calculated as dextrose, and was multiplied by 0.95 to give the sucrose percentage in Table I.

The data of Table I show that in all cases levulose was the predominant sugar, making up over half of the total sugar, with the exception of Red June, Winesap, and Willowtwig. Sucrose was second in quantity, while dextrose was least abundant, comprising less than 20 per cent of the total sugar with the exception of Stayman and Winesap. Even though levulose was the most abundant and dextrose the least abundant sugar in each variety, there was considerable fluctuation between varieties in the relative proportions of the three sugars. For example, in both Winesap and Willowtwig levulose was less than half the total sugar, but in Winesap the dextrose and sucrose contents were nearly equal, whereas in Willowtwig there was over twice as much sucrose as dextrose. Grimes was only average in levulose content, but lowest in dextrose and among the highest in sucrose.

TABLE I—Levulose, Dextrose, and Sucrose Content of Fifteen Apple Varieties at Optimum Maturity

Variety	Grams* Per Fruit	Per Cent of Fresh Weight				Grams Per Fruit				Per Cent of Dry Matter
		Levulose	Dextrose	Sucrose	Total Sugars	Levulose	Dextrose	Sucrose	Total Sugars	
Yellow Transparent A	89.46	4.58	1.11	2.51	8.20	4.10	0.99	2.25	7.34	12.40
Yellow Transparent B	84.68	4.36	1.18	1.42	6.96	3.69	1.00	1.20	5.89	12.20
Red June	104.54	3.84	1.42	3.62	8.88	4.01	1.48	3.78	9.28	13.10
Williams	88.13	4.66	1.57	2.63	8.86	4.11	1.38	2.32	7.81	13.45
Lodi	126.37	5.20	1.39	2.58	9.17	6.57	1.76	3.26	11.59	13.00
Sweet Bough	169.00	6.16	1.35	3.98	11.49	10.41	2.28	6.73	19.42	15.50
Wealthy	132.06	4.97	0.95	2.30	8.22	6.56	1.25	3.04	10.86	12.60
Starking	166.62	5.73	1.27	2.39	9.39	9.55	2.12	3.98	15.65	16.65
Cortland	177.62	5.44	1.38	2.47	9.29	9.66	2.45	4.39	16.50	14.50
Jonathan	163.70	5.90	2.00	2.80	10.70	9.66	3.27	4.58	17.52	16.20
Grimes	130.40	4.91	0.88	3.20	8.99	6.40	1.15	4.17	11.72	14.95
Golden Delicious A	175.94	6.40	1.77	3.62	11.79	11.26	3.11	6.37	20.74	16.45
Golden Delicious B	165.08	5.41	1.83	2.58	9.82	8.93	3.02	4.26	16.21	13.40
Delicious	183.00	5.08	1.94	2.98	10.00	9.30	3.55	5.45	18.30	14.20
Stayman	226.97	4.78	2.00	2.38	9.16	10.85	4.54	5.40	20.79	15.60
Winesap	145.67	5.30	2.70	2.93	10.93	7.72	3 93	4.27	15.92	16.00
Willowtwig	197 46	4.32	1.79	3.98	10.09	8.53	3.53	7.86	19.92	16.40

Note: All samples from University orchard at Urbana with the following exceptions: Yellow Transparent B and Williams from Johnson County; Red June from Union County; Cortland and Starking from McLean County; Golden Delicious B from Pike County.

*Seed and stem not included.

The difference between Delicious and Starking should be noted. In Starking a higher percentage of the total sugars was levulose and a lower percentage was dextrose and sucrose than in Delicious. These data, coupled with the fact that the titratable acidity of the expressed juice from these same fruits was twice as high in Starking as in Delicious (4) shows the importance of examining apple sports for differences other than color in comparison with the parent variety.

In considering environmental influences upon a variety it can be seen that in Yellow Transparent the difference was primarily in the sucrose content. The University-grown fruits were from trees in a higher state of vigor and were more heavily thinned. This may account for the difference in sucrose. The Johnson County Transparents were from a typical commercial orchard for that region. In the case of the Golden Delicious samples, the difference also may be due to growing conditions, since the University fruits were from pruned and thinned trees with an average crop, whereas the Pike County fruits were from an average commercial orchard with a full crop, no thinning and little pruning in recent years.

It seems quite probable that such factors as fertilizer applications, pruning, thinning, diseases, insects, season, and climate would affect the percentage and relative amounts of these sugars in apples. However, the data shown in Table I indicate that, in general, levulose can be expected to be the most abundant sugar and dextrose present in least amount, with sucrose in an intermediate position. The seasonal fluctuation of these sugars in developing apples is being investigated and will be reported in detail later.

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Some Spectral Curves of Maturing Apples[1]

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DURING investigations of apple maturity it was observed that rather specific changes in flesh color accompanied advancing maturity. The flesh color of each variety progressed from the apparently predominately green color of the immature fruit to a color characteristic of the variety at maturity. Because of the extreme difficulty of accurately describing such color changes, a means of description was sought which would decrease the human factor to a minimum and which would provide a permanent record of the color of each sample. Fortunately, a General Electric Automatic Recording Photoelectric Spectrophotometer was available in the Electrical Engineering Department and was used for a study of flesh and skin color changes in maturing fruits of several apple varieties during the 1942 season.

Representative fruits were selected at each picking and from the more highly colored cheek of each fruit a tangential slice 1½ inches or more in diameter and ½ to ¾ inch thick was cut. In all cases the cut was made through the cortical cells of the flesh. The slice was clamped immediately in the machine with the cut surface toward the light source, and the spectral reflection curve recorded on a chart like that shown in Fig. 1. The slice was then reversed with the skin surface toward the light source and the spectral reflection curve recorded on the same sheet. This provided a permanent record of each fruit. The time consumed in recording each curve was 2½ minutes.

In Table I are shown the wavelengths at which reflection maxima and minima were encountered for Jonathan and Golden Delicious at four stages of maturity and for nine other varieties at optimum maturity for commercial harvest and storage. Picking Number 3 was considered to be at optimum maturity for both Jonathan and Golden Delicious. For the sake of brevity, only the one stage of maturity is recorded for the other varieties.

In Fig. 1, the types of curves encountered for flesh and skin of the 11 varieties are shown. The range in wavelength shown at the top of Fig. 1 for each spectral region is in accordance with Hardy (1). The curves for flesh were quite similar in shape with the exception of the violet and blue regions of Cortland and the maximum at 408 millimicrons in Red Rome: this maximum was also found in Willow and Ben Davis but in no other varieties, Table I. In the skin two general types of curves occurred; one characteristic of the yellow varieties, Grimes and Golden Delicious, and the other characteristic of the red varieties. The red fruits used for Table I and Fig. 1 were well colored and with no green evident. Fruits striped red and green from earlier pickings of red varieties showed more reflection in the violet, blue, and shorter green wavelengths but the shape of the curves was typical of that shown for the skin of red varieties in Fig. 1.

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[1] The author gratefully acknowledges the courtesy of Dr. J. O. Kraehenbuehl, Professor of Electrical Engineering, for making available and operating the Spectrophotometer for this work.

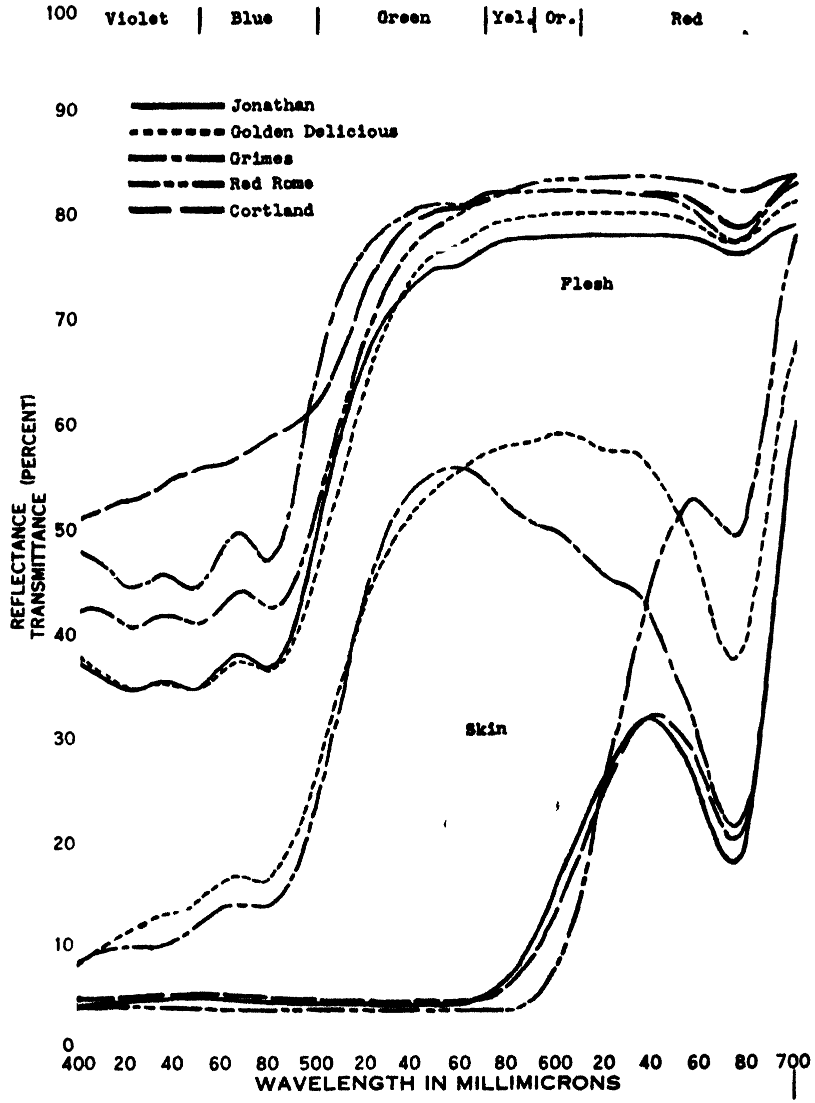

FIG. 1. Types of spectral reflection curves of flesh and skin of 11 apple varieties at optimum maturity, 1942. From wavelengths 682 to 700 millimicrons, Jonathan, Grimes and Cortland skin coincident.

The outstanding feature of the curves in Fig. 1 is the reflection minimum in the general region of wavelength 675 for both flesh and skin. This was true of all samples, which, for each variety, included a range from definitely immature to slightly overmature. The data of Table I show that in Jonathan and Golden Delicious there was an upward trend in both flesh and skin in per cent of reflection at this

TABLE I—REFLECTION MAXIMA AND MINIMA OF APPLE FLESH AND SKIN

Variety	Reflection Maxima								Reflection Minima							
	MM*	R‡	MM	R	MM	R	MM	R	MM	R	MM	R	MM	R	MM	R
							Flesh									
Jonathan 1† . .	—	—	436	39.7	468	42.5	596–620	78.0	424	38.7	449	38.6	481	40.5	674	75.2
Jonathan 2 . .	—	—	437	35.2	468	37.7	618–638	78.0	424	34.4	448	34.5	480	36.5	676	76.5
Jonathan 3 .	—	—	437	34.6	469	36.6	632–646	78.0	425	34.0	450	33.6	482	35.0	677	77.0
Jonathan 4 .	—	—	436	34.8	469	37.4	638–650	78.5	424	34.0	450	33.7	481	36.0	675	77.6
Golden Delicious§ 1	—	—	436	35.0	469	37.5	594–604	78.7	425	34.6	448	34.6	481	36.3	676	73.3
Golden Delicious 2	—	—	437	35.0	469	37.1	586–604	79.2	425	34.4	448	34.3	481	36.1	676	74.8
Golden Delicious 3	—	—	435	34 8	468	36.8	630–636	79 8	425	34.2	448	34.2	480	36.0	675	77.0
Golden Delicious 4	—	—	437	37.0	469	38.5	612–638	80.5	426	36.5	448	36.5	480	38.0	676	79.0
Grimes . .	—	—	435	45.0	467	49.4	582–606	82.0	424	44.0	447	43.7	480	46.6	675	76.8
Cortland. . .	—	—	—	—	—	—	590–636	82.0	—	—	—	—	—	—	677	78.6
Delicious . . .	—	—	436	28 8	467	31.2	590–636	71.0	424	28.2	448	28.3	480	29.8	676	65.7
Starking . .	—	—	436	36.7	469	38.5	630–658	74.7	424	36.1	449	35.8	481	37.2	675	74.0
Stayman . .	—	—	437	38.9	469	42.5	590–634	79.5	425	38.0	449	37.6	482	40.1	676	75.3
Winesap .	—	—	437	36.2	469	39.3	610–646	78.0	425	35.2	450	35.0	482	37.1	677	75.8
Red Rome . . .	406	42.0	438	41.5	470	43.6	598–656	83.0	425	40.5	449	40.7	482	42.3	676	82.1
Willow . . .	405	41.3	437	40.2	469	42.6	620–656	82.3	425	39.2	450	39.0	482	41.0	676	81.0
Ben Davis	408	44 6	437	44 2	469	46.5	634–664	80.5	424	43.2	449	43.5	480	45.5	675	80.2
							Skin									
Jonathan 1 .	—	—	—	—	460	5.5	636	31 5	—	—	—	—	490	5.2	675	16.2
Jonathan 2 .	—	—	—	—	450	4.6	639	31.8	—	—	—	—	530	4.3	675	18.0
Jonathan 3 .	—	—	—	—	440	4 5	651	24.7	—	—	—	—	550	4.1	676	17.0
Jonathan 4	—	—	—	—	440	4.0	658	27.0	—	—	—	—	560	3.6	674	23.2
Golden Delicious 1	—	—	—	—	—	—	560	54.3	—	—	—	—	—	—	676	24.3
Golden Delicious 2	—	—	—	—	467	18.6	566	57.8	—	—	—	—	477	18.3	676	28.5
Golden Delicious 3	—	—	—	—	467	16.4	604	58.6	—	—	—	—	477	15.9	675	37.2
Golden Delicious 4	—	—	—	—	467	18.6	602	61.5	—	—	—	—	478	18.2	676	42.0
Grimes .	—	—	—	—	467	13.7	556	55.5	—	—	—	—	476	13.5	675	20.7
Cortland	—	—	—	—	448	5 0	642	32 0	—	—	—	—	540	4.4	675	19.9
Delicious .	—	—	—	—	440	4.0	655	34.9	—	—	—	—	536	3.5	674	30.0
Starking	—	—	—	—	430	5.6	659	52.2	—	—	—	—	510	5.0	673	50.7
Stayman . .	—	—	—	—	440	5.5	643	32.7	—	—	—	—	554	4 7	676	21.7
Winesap.	—	—	—	—	455	4.5	654	32.3	—	—	—	—	540	4 0	676	25.5
Red Rome. . . .	—	—	—	—	440	3.9	658	52.5	—	—	—	—	560	3.5	675	49.2
Willow	—	—	—	—	456	5.0	639	43.8	—	—	—	—	538	4.0	675	27.3
Ben Davis . .	—	—	—	—	450	4.0	656	49.6	—	—	—	—	534	3.5	674	44.7

*Wavelength in millimicrons.
‡Per cent reflection.
†Jonathan picking dates: 1. Sep 14; 2. Sep 21; 3. Sep 28; 4. Oct 5, 1942.
§Golden Delicious picking dates: 1. Sep 15; 2. Sep 24; 3. Oct 10, 4. Oct 8, 1942.

wavelength with increasing maturity. This was also the case with Grimes and, in general, with the other varieties, but there were some discrepancies. In several cases pairs of fruits were selected from a picking as being definitely different in degree of maturity; in each case the fruit selected as the riper had the greater reflection at this point for both skin and flesh, definitely indicating that there was a trend toward increasing reflection with increasing maturity.

The varietal differences in per cent reflection at the wavelength region 675 are noteworthy, ranging in the flesh from 65.7 for Delicious to 82.1 for Red Rome, and in the skin from 17.0 for Jonathan to 50.7 for Starking.

Table I shows that, in the skin of Golden Delicious, the wavelength at which the maximum reflection immediately preceding the minimum at 675 was reached increased from 560 to 602 as maturity progressed and the per cent of reflection increased. In Grimes, however, the maximum remained at 556 millimicrons but the per cent of reflection increased. Jonathan showed a shift to a longer wavelength at this maximum but the per cent of reflection decreased. Apparently, the behavior of this maximum varies considerably with variety.

The relative uniformity of points of maxima and minima in the flesh in the violet and blue regions is interesting, but no definite association appeared between per cent of reflection and change in maturity in these regions. The comparatively high reflection in violet and blue of Cortland flesh should be noted, since it was the only white-fleshed sort used.

Other features of interest were: the high per cent of reflection of the longer green, yellow, orange, and red wavelengths from the flesh of all varieties regardless of stage of maturity; the high reflection of red wavelengths from the skin of the two yellow varieties; and the increasing per cent of reflection from both flesh and skin in the longest red wavelengths.

It was hoped that this work might provide information which would aid in the establishment of definite maturity standards, since definite changes in flesh color are observable as maturity progresses. While a number of interesting facts are revealed by the curves, it is felt that the reflection behavior in the general region of 675 millimicrons in both flesh and skin offers the most promising field for further study. This general problem is presented at this time with the hope that it may provoke study by those investigators who have the necessary equipment and personnel. Because of the preliminary nature of the present report no attempt is made to interpret maxima and minima on the basis of the pigments present in the fruits, but the work of Zscheile and his associates (2, 3) indicates that considerable study of this phase of the problem is desirable.

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The Influence of Amount of Crop and Harvesting Maturity on Bitter Pit in Okanagan-Grown Newtown Apples[1]

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BITTER PIT, as it occurs in Okanagan-grown Newtown apples, is characterized by small, brownish pits in the flesh of the fruit. These usually occur in a shallow area just beneath the skin and, in advanced stages, are evident from the exterior. Occasionally the pits extend deeply into the flesh. Typical examples are shown in Fig. 1.

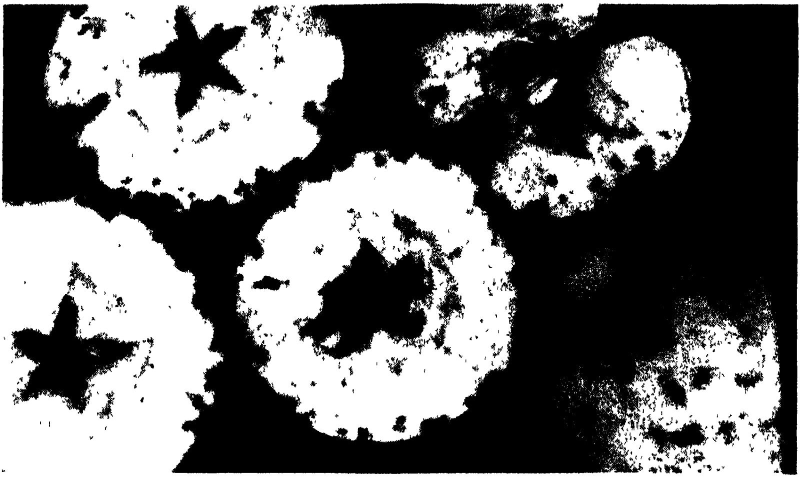

FIG. 1. Bitter pit in Newtown. (Photo by J. E. Britton).

Experiments designed to ascertain the influence of the amount of crop carried by the trees and the stage of maturity at which the fruit is harvested on development of bitter pit in Newtown apples have been conducted for five years. The experiments have involved the study of over 500 bushel boxes of apples picked from over 70 individual trees located in seven different orchards. The general procedure has been to select, in each orchard, equal numbers of trees carrying heavy and light crops and to make pickings from each of these trees beginning before the customary harvesting season and continuing for a period of about 5 weeks. At harvest time the maturity of the fruit from each tree has been recorded using such criteria as skin colour, flesh colour and the iodine test developed by Carne *et al.* (1). The fruit from each tree has then been stored separately for determination of quality, bitter pit and other disorders such as scald and brown core.

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[1] This paper consists largely of extracts from a more comprehensive report entitled "The Influence of Some Horticultural Practices on Bitter Pit in Okanagan-Grown Apples", prepared by J. E. Britton, D. V. Fisher, and R. C. Palmer, for publication in "Scientific Agriculture".

AMOUNT OF CROP AND BITTER PIT IN NEWTOWN

Fruit obtained from the Lucich orchard in 1939 and 1940 provided evidence regarding the influence of amount of crop on susceptibility of Newtown to bitter pit. These data are presented in Table I.

TABLE I—AMOUNT OF CROP AND BITTER PIT IN NEWTOWN APPLES OBTAINED FROM LUCICH ORCHARD

Tree No.	Performance 1939		Performance 1940	
	Crop	Bitter Pit (Per Cent)	Crop	Bitter Pit (Per Cent)
1	Heavy	2	Light	35
3	Heavy	2	Light	10
4	Heavy	1	Light	11
7	Heavy	14	Light	5
8	Heavy	1	Light	13
2	Light	2	Heavy	2
5	Light	4	Heavy	0
6	Light	17	Heavy	3
9	Light	1	Heavy	1
10	Light	9	Heavy	0

The figures incorporated in Table I indicate that in most cases the fruit from individual trees was more susceptible to bitter pit in the light crop year than in the heavy crop year. In this connection it is of interest to note that while tree No. 7 was classified as heavy crop in 1939 it produced, in both 1939 and 1940, fruit of the large angular, yellow coloured type commonly found on light crop trees.

Additional evidence concerning the susceptibility of apples from light crop trees to bitter pit was secured from fruit obtained in the Davenport, Maynard, Corbett, King and Cossentine orchards. The percentages of this fruit which developed bitter pit are indicated by the figures presented in Table II.

TABLE II—AMOUNT OF CROP AND BITTER PIT IN NEWTOWN APPLES FROM MAYNARD, DAVENPORT, CORBETT, KING AND COSSENTINE ORCHARDS

Orchard	Year	Average Bitter Pit in Trees Carrying (Per Cent)		
		Heavy Crop	Light Crop	Medium crop
Davenport	1939	1	6	–
Maynard	1940	3	20	–
	1941	1	12	–
	1942	0	20	1
Corbett	1941	0	8	
	1942	0	5	2
King	1941	0	0	–
	1942	0	1	2
Cossentine	1941	0	0	–
	1942	0	3	1

It will be noted from the data presented in Table II that regardless of orchard or year of harvest there was a consistent tendency for the fruit from light crop trees to develop more bitter pit than that from heavy crop trees. On the other hand in the fruit from the King and Cossentine orchards in both 1941 and 1942 very little bitter pit developed even in the fruit from light crop trees.

In 1942 ten trees carrying about half a full crop were selected in each of the Maynard, Corbett, King and Cossentine orchards. As indicated by data presented in Table 2 a comparatively small percentage of these apples from medium crop trees developed bitter pit.

DATE OF PICKING AND BITTER PIT IN NEWTOWN

The results obtained with date of picking experiments conducted in the Lucich and Maynard orchards in 1940 are indicative of the influence of maturity at harvest time on susceptibility of Newtown to bitter pit. These results are presented in Table III. Each figure indicates the percentage of bitter pit which developed in over 400 apples picked from a group of five heavy or light crop trees.

TABLE III—DATE OF PICKING AND BITTER PIT IN NEWTOWN APPLES OBTAINED FROM LUCICH AND MAYNARD ORCHARDS, 1940

Orchard	Crop	Bitter Pit in Fruit From Each Picking (Per Cent)				
		Sep 23	Sep 30	Oct 7	Oct 15	Oct 21
Lucich .	Heavy	0	4	1	0	0
Lucich .	Light	29	22	14	6	7
Maynard .	Heavy	1	4	3	1	0
Maynard.	Light	23	32	31	8	10

It will be noted that in the fruit from the light crop trees in both orchards there was more bitter pit in the early than in the late pickings. In the fruit from the heavy crop trees there was very little bitter pit regardless of picking date. Similar results were secured in 1941 and 1942 with fruit from the Maynard and Corbett orchards, but very little bitter pit developed in the fruit from the King and Cossentine orchards even when picked early in the season from light crop trees.

MATURITY INDICES FOR NEWTOWN

Harvest records on Newtown apples indicate that the seed colour changes to dark brown several weeks before the fruit is ready to pick. Changes in hardness have not proved sufficiently great or consistent to be of value as a maturity test. Skin colour and flesh colour were observed to turn from green to yellowish tints much earlier on light crop than on heavy crop fruits. In fact the fruit on heavily loaded trees was often quite green in colour when ready to pick. On the other hand the iodine test revealed that the starch disappeared from the flesh of light crop fruits less rapidly and consistently than from that of heavy crop fruits.

In making the iodine test the solution was prepared by dissolving 10 grams potassium iodide and 2.5 grams iodine in 1000 cubic centimeters of water. Representative apples were cut in half equatorially and the cut surface immersed in the solution for about half a minute, then allowed to stand, cut side up, for half a minute before rinsing in water. After removing the excess water with blotters the pattern made by interaction of the iodine with the starch in the flesh of the apple was observed.

When used on fruits from trees carrying a full crop the iodine test proved a very satisfactory index of maturity. Fruit picked when the core area contained starch tended to be poor in quality and more subject to bitter pit, scald, brown core and shrivelling than that picked when the core was free of starch. Fruit left on the tree until starch disappearance from the flesh had produced a definite mottled effect, developed good quality and was resistant to storage troubles, but practical considerations necessitate commencement of picking before this stage is reached. The range of starch-iodine reaction in fruit from heavy crop trees picked on September 23, September 30 and October 21, 1940, is shown in Fig. 2.

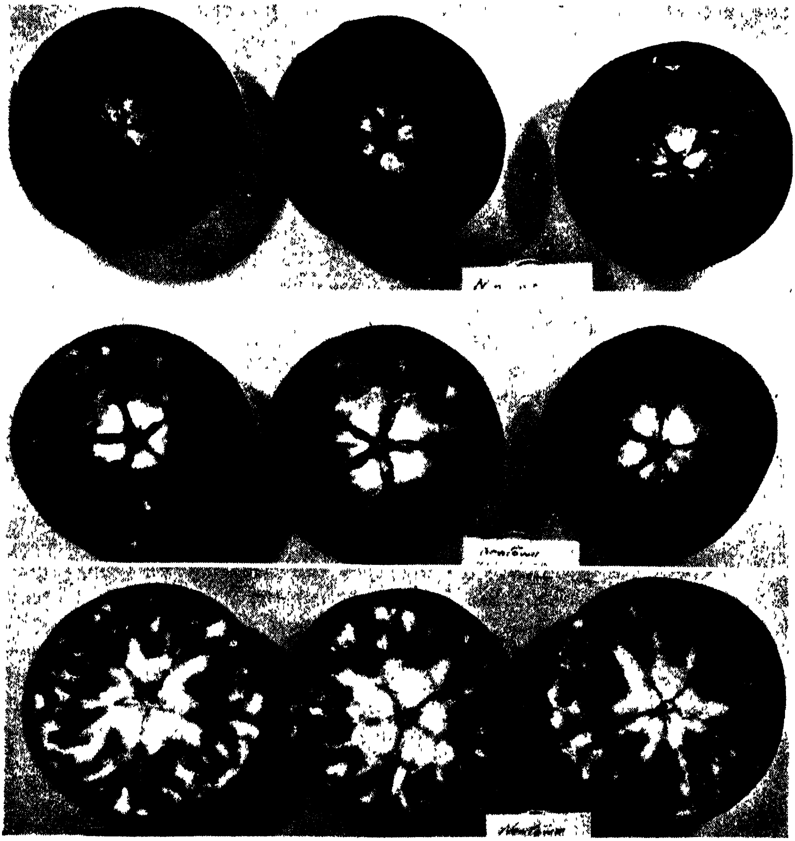

FIG. 2. Starch-iodine reaction in Newtown picked from heavy crop trees in 1940. Top row picked September 23, centre row September 30, bottom row October 21. Specimens in centre row illustrate reaction at satisfactory maturity. (Photo by J. E. Britton).

While maturity was influenced somewhat by seasonal weather conditions, Newtown apples were seldom ready to harvest before October 3, and quality was improved by harvesting 1 or 2 weeks later. In this connection, however, growers have learned from experience that danger of loss from frost makes it desirable to have the entire crop off the trees by October 20.

DISCUSSION

The results obtained in these investigations indicate that losses from bitter pit in Okanagan-grown Newtown apples can be materially reduced by picking the fruit at the proper stage of maturity. However, they indicate that regardless of harvesting procedure the fruit from trees carrying less than a third of a full crop is likely to develop bitter pit. This light crop fruit constitutes only a small percentage of the total crop, yet when mixed with the main tonnage may necessitate costly repacking or even payment of claims after shipment to market. Accordingly, there are good reasons for segregating the fruit from light and heavy crop trees. The apples on light crop trees average larger than those produced by heavy crop trees, but appreciable quantities of small apples are produced even on light crop trees. Thus the regular packing house procedure of grading for size does place much of the fruit from light crop trees in the large size groups, which can then be sold for processing. Nevertheless, packing house grading distributes the small sizes from light crop trees amongst the bulk of the tonnage from heavy crop trees necessitating repacking in seasons when bitter pit is prevalent.

Grading for colour has been suggested as a simple and effective means of separating the fruit from light and heavy crop Newtown trees after it reaches the packing house. In this connection it is true that the fruit from light crop trees is usually yellow in colour. In addition, light crop fruit is also longer and more angular in shape than that from very heavy crop trees. However, annual bearing trees carrying quite good crops usually produce fruit intermediate in colour between green and yellow. Thus grading for yellow colour, while desirable from the standpoint of producing a uniform appearing pack, would group together the small quantities of pit-susceptible fruit from light crop trees and comparatively large quantities of somewhat similar coloured but pit-resistant fruit from trees carrying medium crops.

Accordingly, the logical place to segregate the fruit from light-crop trees is in the orchard at harvest time. The chief difficulty involved in segregating fruit from light crop trees lies in deciding which trees should be included in the light crop classification. Some trees have been observed on which individual branches alternate in bearing, one part of a tree carrying a heavy crop in the same year that other branches carry a light crop. On such trees the fruit from the heavy crop branches usually behaves like that from heavy crop trees. As a general rule, fruit from trees carrying less than a third of a normal crop following a heavy crop is likely to prove very susceptible to bitter pit.

Maturity indices such as seed colour, skin colour, and flesh colour suggest that apples on light crop trees mature earlier than those on heavy crop trees. On the other hand the iodine test indicates that starch disappearance takes place more slowly and less consistently from apples on light crop than from those on heavy crop trees. Furthermore, the longer light crop apples are left on the trees the less susceptible they become to bitter pit, brown core, and scald. Thus, there are good reasons for leaving the light crop trees unpicked until after the fruit from heavy crop trees has been harvested. However, the question as to whether it is most practical to pick the light crop trees before, after or at the same time as the heavy crop trees depends on conditions and facilities in each individual orchard. The factor of primary importance is to make sure that the fruit from trees carrying less than a third of a crop is kept separate from the main tonnage. This light crop fruit is not only susceptible to bitter pit but also to such storage troubles as brown core, and scald. Claims and costly repacking would be prevented by disposing of it directly to processing plants.

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Relation of Ethylene Production to Respiration and Ripening of Premature Pears[1]

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IN a previous publication (2) the formation of ethylene was shown to be an integral part of the metabolism of mature pears during storage and ripening. Little information is available, however, regarding the formation of ethylene by premature fruits, especially with respect to the amounts produced during the period immediately preceding the climacteric. Epinastic tests have indicated that immature Bartlett pears produce ethylene, although apparently in minute quantities incapable of affecting the metabolism of the fruit. Kidd and West (3) have presented evidence for the production of ethylene by immature apples, and Denny (1) found that the emanations from green-apple tissue caused epinasty of the potato plant.

The production of ethylene during the pre-climacteric period is of special significance, since if sufficient quantities are formed during this critical period, respiration and ripening of the fruit will undoubtedly be affected. Kidd and West (4), from their extensive work with apples have stated that the climacteric rise in respiratory activity is almost certainly due to auto-stimulation from ethylene produced by the fruit during the normal course of metabolism.

In this paper the relation of ethylene to the respiration and ripening of pears removed from the trees at premature stages of development is considered. The experiments were designed especially to determine whether or not ethylene is required for the ripening of these fruits.

MATERIALS AND METHODS

The pears used in these experiments were obtained from the Southern Oregon (Medford) district. The fruit was received in the laboratory approximately 16 hours after picking and treated as described later.

Determinations of carbon dioxide and ethylene production were made simultaneously on the same samples of fruit according to the method described previously (2). In those cases where the amounts of ethylene produced was insufficient to be determined chemically, epinasty of tomato plants was used as a biological indicator of its presence in the emanations from the fruit.

EXPERIMENTAL RESULTS

Production of Ethylene by Immature Pears as Indicated by Epinastic Response:—The minimum quantity of ethylene that can be determined by the chemical method used is 1 part in 100,000 by volume. Preliminary studies showed that while the amount of ethylene produced by immature pears shortly after picking was too low to be measured by this method, the rate of production during the period

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immediately preceding the climacteric was within the range that can be chemically analyzed. In order to obtain an approximate estimate of the quantity of ethylene produced by immature pears shortly after removal from the trees, several fruits were enclosed with a tomato plant and the epinastic response observed during a 24-hour period. The results of these tests are as follows: Immature Bartletts when tested the first day after picking caused only slight epinasty. Since the pure gas at a concentration of 1 part in 22 million produced moderate epinasty during the same period of time, it is apparent that the ethylene produced by these fruits was below this amount. Immature Anjous caused no epinasty when tested the first or the seventeenth day following picking. The emanations from either freshly-picked Bartletts or Anjous had no observable effect on the respiration of the fruit. From these results it is assumed that immature pears shortly after picking do not produce ethylene in sufficient quantities to stimulate respiration and ripening.

Effect of Ethylene on Respiration and Ripening:—A sample of Anjou pears was picked on July 7 when the average weight per fruit was 64 grams. Duplicate lots of 25 pears were placed in closed desiccators and rates of respiration determined daily. As shown in Fig. 1,

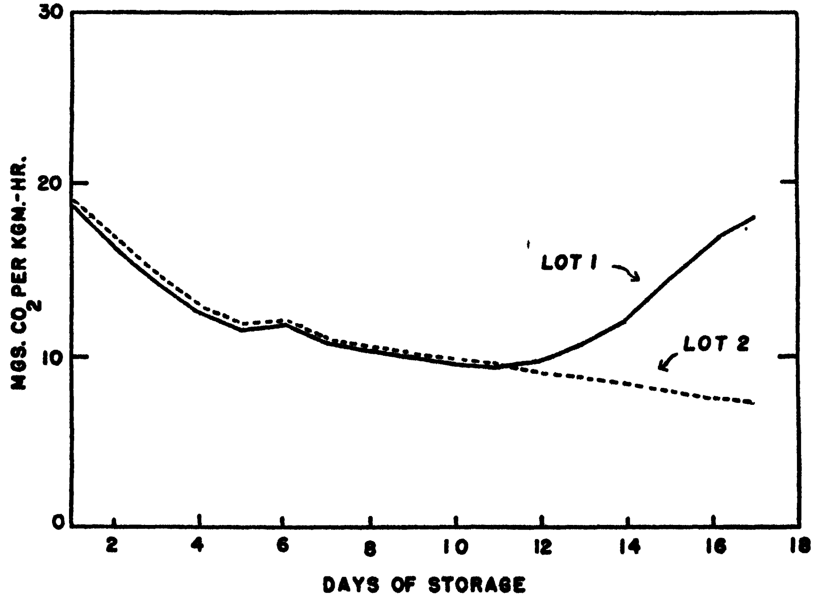

FIG. 1. Effect of ethylene on respiration of immature Anjou pears.

there was a gradual decrease in the rate of CO_2 production from approximately 18 milligrams to 9 milligrams per kilogram hour during the first 10 days. This decrease in respiratory activity together with the epinasty tests shows clearly that the fruit was not producing ethylene in amounts sufficiently great to affect respiration or ripening.

To determine if the respiration of these immature pears could be stimulated by the presence of ethylene, Lot 1 was treated on the tenth day with a concentration of 1: 1000. As shown in Fig. 1, the rate of respiration immediately increased. Respiratory activity of the untreated lot continued to decline and showed no increase during the remainder of the experiment. Fruit of the treated lot was fully ripe at the termination of the experiment.

In a second experiment, immature Bartlett pears picked on July 11 were divided into three uniform lots, each consisting of 25 fruits. Lot 1 was placed in a closed desiccator and treated daily for 7 days with ethylene. Lot 2 was kept in a closed container, but no synthetic ethylene was added during the course of the experiment. Ethylene and CO_2 analyses were made daily on these two samples. Lot 3 was placed in a desiccator which was aerated with a constant flow of fresh air (20 liters per hour), the outgoing air being bubbled through a spiral glass-tube scrubber containing KOH solution to absorb the evolved CO_2. By this procedure no ethylene was allowed to accumulate within the container. No chemical analyses for ethylene were conducted on this lot of fruit, since epinastic tests showed the amounts produced to be below the sensitivity of the chemical method.

As presented in Fig. 2, the sample of fruit artificially treated with ethylene (Lot 1) showed an immediate increase in respiration, the peak of the climacteric occurring on the seventh day. Ethylene began to be produced in chemically-measurable quantities on the second day, and rapidly increased to a peak value of 6.26 milliliters per kilogram day on the eighth day. The fruits were fully ripe at this time. The sample of fruit kept in the closed container but not artificially treated with ethylene (Lot 2) did not show an increase in respiratory activity until the fifth day, when ethylene began to be produced in measurable quantities. The fruit was fully ripe on the tenth day. The fruit which was constantly aerated (Lot 3) maintained a low rate of respiration for 10 days and showed only a slight increase thereafter. At the termination of the experiment, two of the pears had started to ripen but the remainder were still firm and green.

These data show that immature pears which are producing ethylene in amounts that can be detected only by sensitive biological methods, do not ripen at all, or only very slowly, if the emanations formed by the fruit are removed from the storage atmosphere. If, however, the emanations are allowed to accumulate or if synthetic ethylene is incorporated in the atmosphere, both respiration and ripening are stimulated. Thus, it appears to be established beyond any reasonable doubt that the climacteric and the ripening of these fruits is dependent upon the presence of ethylene in at least a certain minimum concentration.

The data shows further that during the preclimacteric period, there is a very great increase in the rate at which ethylene is formed in the fruit tissues. Calculations based upon the data of epinastic and chemical tests reveal that there was at least a 220-fold increase in the rate of ethylene production by Bartlett pears (Lot 2) during the first 5 days following picking. During this rapid increase, the minimum effective concentration necessary for activation of the climacteric and

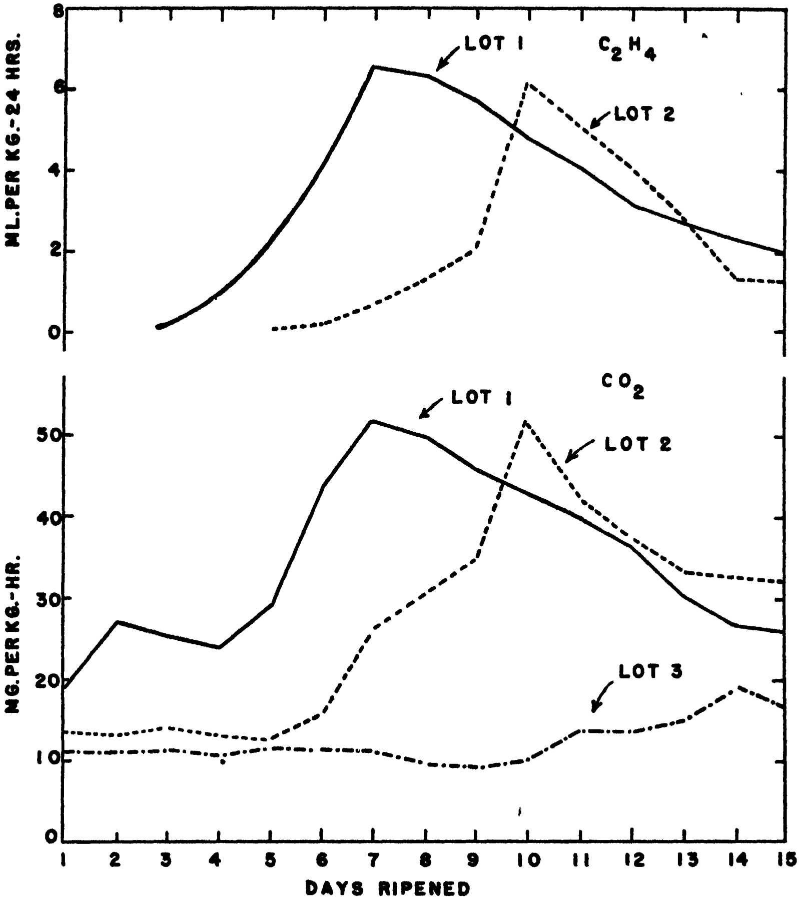

FIG. 2. Respiration and ethylene production by Bartlett pears kept in aerated and unaerated containers.

ripening apparently was attained. In view of this and the other data presented, the ethylene formed by pears during the course of metabolism cannot be regarded as an inert by-product of metabolism but as a vital factor definitely influencing the respiration and ripening of the fruit.

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The Effects of Storage Upon the Ascorbic Acid Content of Some West Virginia Apples[1]

By VELMER B. FISH, *West Virginia Agricultural Experiment Station, Morgantown, W. Va.*

THE ascorbic acid content of apples has been studied by many investigators in the past decade. The range of concentration which has been reported is quite extensive including values from about 1 milligram per 100 grams of apple to over 30 milligrams per 100 grams.

Birch, Harris, and Ray (2) showed that there was a wide variation of ascorbic acid between varieties and that the peel contained from four to six times as much ascorbic acid as the corresponding weight of cortex. Keys (6), working with a variety of New Zealand apples, found from 15 to 20 milligrams of ascorbic acid per 100 grams of peeled flesh. He found that concentration of ascorbic acid much greater in the peel than in the flesh. Keys (6) and Harris and Oliver (5) found that following the crushing of apple tissue the loss of ascorbic acid was very rapid. Harris and Oliver point out that the concentration of dehydroascorbic acid is very low in all fruits and vegetables. They consider it probable that the large amounts of dehydroascorbic acid, reported by some investigators to be present in fruits and vegetables, are due to the rapid oxidation of ascorbic acid to dehydroascorbic acid during the analysis.

The following acid solutions have been used to prevent oxidation during extraction: 5 per cent sulfuric acid, 10 per cent trichloroacetic acid, 10 per cent acetic acid, 5 per cent metaphosphoric acid and 0.4 per cent oxalic acid. The use of metaphosphoric acid is perhaps most extensive. Ponting (8) has studied the stability of ascorbic acid in the various acid extracting agents commonly used to remove ascorbic acid from plant material. The results reported show that metaphosphoric acid and oxalic acid have the greatest stabilizing action upon the ascorbic acid. Sulfuric acid was shown to be unsatisfactory since it decolorized 2,6-dichlorobenzenoneindophenol and did not effectively stabilize the ascorbic acid. The method most widely used for the determination of ascorbic acid is the titration of the ascorbic acid with standard solutions of 2,6-dichlorobenzenoneindophenol. The method used in this experiment was based on that reported by Clegg and Satterfield (3) in 1940. It was difficult to titrate colored extracts to a visual end point and for such titrations the method proposed by Harris, Mapson and Wang (4) was used. Kirk and Tressler (7) also found that electrometric titrations were satisfactory when a titrimeter was used.

The loss of ascorbic acid from apples during storage under various conditions has been studied extensively. In general the loss of ascorbic acid during storage at temperatures above 0 degree C has been shown to be considerable. Scupin (9) recently reported that apples stored from December until mid-March at 1 degree C to 5 degrees C showed

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little or no loss of ascorbic acid. However, in the period of storage from mid-March until mid-July, at temperatures of from 4 to 12.5 degrees C, the apples lost about 50 per cent of their ascorbic acid. Scupin reported that storage of apples at —0.5 to —1.0 degree C caused the apples to gain about 50 per cent in their ascorbic acid concentration during storage from December until July. However, a very rapid loss of ascorbic acid during storage was reported by Zilva, Kidd, and West (11). These investigators reported that apples lost almost all of their ascorbic acid during storage for 3 months in air at a temperature of —5 degrees C. During the same period of storage in air at a temperature of —10 degrees C the loss was about 70 per cent. They reported that no loss occurred during storage for 6 months in a vacuum at —20 degrees C, and a 25 per cent loss during storage in a vacuum at —10 degrees C and —5 degrees C. Batchelder (1) reported that Delicious apples lost approximately 17 per cent of their ascorbic acid during storage for 3 months at 7 degrees C and 25 per cent during storage for 6 months. Wolf (10) found that the average concentration of ascorbic acid in 37 varieties of German apples was 16.5 milligrams per 100 grams of apple tissue. He also found that prolonged storage at —0.5 degree C resulted in a loss of about 30 per cent.

The present study was made in order to determine the ascorbic acid concentration in the edible portion of some apples and to determine the effects of storage at 0 to 2 degrees C upon the ascorbic acid content.

A total of six varieties was analyzed for ascorbic acid as soon as they were received in September and October. They were again analyzed for ascorbic acid after storage periods of 2 months and 4 months. Samples of two of the varieties were received from different sources and were treated separately. Commercial samples of six varieties of the apples were received from Kearneysville, West Virginia and samples of Grimes and Delicious apples were received from Romney, West Virginia in September and October of 1942.

ANALYTICAL METHODS

Sampling:—The core was removed from each apple by means of a cork borer and radial sections were removed from opposite portions of the apple. The sections were weighed to the nearest hundredth of a gram as rapidly as possible and were placed in a glass mortar containing 20 milliliter of a solution of 8 per cent acetic acid and 4 per cent metaphosphoric acid. Approximately 15 grams were taken from each apple. Similar samples were taken from two additional apples and the entire mixture was thoroughly ground with 14 grams of acid-washed sand. This amount of the sand used was equivalent to a volume of 5 milliliter. The mixture was transferred to a 250 milliliter volumetric flask using a little of the acid mixture diluted with an equal amount of distilled water. Similar samples were taken from three additional apples and ground with the same amount of acid solution and sand as described above. This sample was added to the same 250 milliliter volumetric flask and the mortar was thoroughly rinsed with the dilute acid solution. The flask was filled to volume with the dilute acid, stoppered, and mixed thoroughly. The mixture was allowed to stand for 15 to 20 minutes with occasional mixing. The material was then mixed and portions were transferred to clean dry centrifuge tubes and centrifuged at about 3000 revolutions per minute for 5 minutes. The reduced ascorbic acid was determined by titrating 10 milliliter portions of the supernatant solution with a standard solution of sodium 2,6-dichlorobenzenoneindophenol. Approximately 0.001 N dye was used.

Titration:—The extracts obtained from peeled apples were titrated to a faint pink end-point which would persist for 30 seconds. The extracts obtained from samples of whole red apples were colored by the skin pigments and could not be titrated to a visual end-point. These samples were titrated potentiometrically by means of a type K potentiometer equipped with a thermionic amplifier. The cell consisted of a saturated calomel half-cell as the negative electrode and a bright platinum electrode immersed in the apple extract as the positive electrode. The cell was completed by means of a saturated potassium chloride agar bridge. The solution was agitated by an electric stirrer. The stirring was not vigorous enough to whip air into the solution.

It was found that the electromotive force remained quite constant until the end-point was approached. The addition of one drop of the dye produced a marked deflection of the galvanometer as the end-point was approached but until it was reached the galvanometer soon drifted back to zero. At the end-point the return of the galvanometer toward zero was so slow as to afford a very satisfactory indication of the end-point. This means of titration was checked against the visual method using colorless apple extracts as well as standard ascorbic acid solutions and found to agree very closely. An accurate micro burette graduated to 0.02 milliliter was used for all titrations.

The concentration of ascorbic acid in the apples was calculated as follows:

$$\frac{(\text{Ml. titration} - \text{Ml. blank}) \times \text{N of dye} \times 88.03 \times 240 \times 100}{\text{Grams of sample} \times 10} =$$

Milligram of ascorbic acid per 100 grams of apple.

RESULTS

The ascorbic acid content of the various varieties of apples was determined as soon as the apples were received and after storage periods of 2 and 4 months. The data obtained for the cored apples are shown in Table I. Each value given is the average of five composite samples each sample representing sections from six apples.

In general there was a considerable loss of ascorbic acid during the first 2 months of storage. During the second 2-month storage period there was in general a small loss of ascorbic acid. The exceptions were probably due to sample variation which was quite pronounced in the apples analyzed.

The same varieties of apples were peeled with a mechanical peeler and the flesh was analyzed for ascorbic acid. The data which were obtained are shown in Table II.

TABLE I—THE ASCORBIC ACID CONTENT OF CORED APPLES AS RECEIVED AND AFTER STORAGE AT 0 DEGREE C TO 2 DEGREES C

Variety and Source	Milligrams of Ascorbic Acid Per 100 Grams of Apple				
	As Received	After 2 Months Storage	Per Cent Loss	After 4 Months Storage	Per Cent Loss
Grimes, Kearneysville	2.59	2.10	22.8	1.92	25.8
Delicious, Kearneysville	1.96	1.52	23.5	1.37	30.1
Starking, Kearneysville	1.70	1.50	11.8	1.50	11.8
York, Kearneysville	3.74	2.80	25.1	2.78	26.7
Stayman, Kearneysville	2.74	2.02	26.3	2.19	20.1
Rome, Kearneysville	2.93	2.33	20.4	1.94	33.8
Grimes, Romney	3.33	2.36	29.1	2.73	18.0
Delicious, Romney	4.50	2.40	46.7	2.09	53.6

TABLE II—THE ASCORBIC ACID CONCENTRATION OF THE FLESH OF APPLES AS RECEIVED AND AFTER STORAGE

Variety and Source	Milligrams of Ascorbic Acid Per 100 Grams of Flesh				
	As Received	After 2 Months Storage	Per Cent Loss	After 4 Months Storage	Per Cent Loss
Grimes, Kearneysville	1.68	1.41	16.1	1.56	7.14
Delicious, Kearneysville	1.65	1.34	18.8	1.01	38.8
Starking, Kearneysville	1.18	1.29	–6.12	1.20	–1.7
York, Kearneysville	2.71	1.99	26.6	2.15	20.6
Stayman, Kearneysville	1.94	1.57	19.1	1.80	7.2
Rome, Kearneysville	1.53	1.53	0.0	1.44	5.9
Grimes, Romney	2.14	1.66	22.4	2.10	1.9
Delicious, Romney	2.88	1.68	41.7	1.84	36.1

The ratios of the concentration of ascorbic acid in the whole (cored) apple to the concentration in the flesh are shown in Table III.

TABLE III—THE RATIOS OF THE CONCENTRATION OF ASCORBIC ACID IN THE WHOLE (CORED) APPLE TO THE CONCENTRATION IN THE PEELED (CORED) APPLE

Variety and Source	Ratios		
	As Received	After 2 Months Storage	After 4 Months Storage
Grimes, Kearneysville	1.54	1.49	1.23
Delicious, Kearneysville	1.19	1.14	1.35
Starking, Kearneysville	1.44	1.16	1.25
York, Kearneysville	1.38	1.40	1.29
Stayman, Kearneysville	1.41	1.29	1.22
Rome, Kearneysville	1.91	1.52	1.35
Grimes, Romney	1.56	1.42	1.30
Delicious, Romney	1.56	1.43	1.13

There was a general decrease in the ratios during the storage period which would indicate that the ascorbic acid was lost from the skin portion more rapidly than from the flesh during storage. From the data shown in Table II it is evident that there was a rather slight loss of ascorbic acid from the flesh during storage.

The rapid oxidation of the ascorbic acid of apple tissue upon exposure to air has been reported by Harris and Oliver (5). These investigators showed that dehydroascorbic acid was first formed and that treatment with H_2S would recover most of the ascorbic acid if the exposure to air was less than 1 minute. From the results reported there was apparently a rapid destruction of the dehydroascorbic acid since after 1.5 minutes only 63.6 per cent of the ascorbic acid could be recovered by treatment with H_2S.

In the present work a few experiments were conducted to determine the rapidity with which ascorbic acid in apple tissue was oxidized when exposed to air. In order to demonstrate this loss of ascorbic acid duplicate samples were removed from the same apple. One sample was weighed under a solution of 4 per cent meta phosphoric acid and 8 per cent acetic acid. The other sample was weighed and ground with sand. After a definite time acid was added and the samples were both analyzed for ascorbic acid. The results of these experiments are shown in Table IV.

TABLE IV—THE LOSS OF ASCORBIC ACID FROM APPLE TISSUE ON EXPOSURE OF THE GROUND TISSUE TO AIR

Sample	Milligrams Ascorbic Acid Per 100 Grams of Flesh			
	No Exposure	2 Minute Exposure	10 Minute Exposure	15 Minute Exposure
[illegible]	4.10	—	—	0.13
[illegible]	2.90	—	—	0.37
[illegible]	4.83	—	—	0.23
[illegible]	1.77	—	0.14	—
[illegible]	4.28	—	0.13	—
[illegible]	1.54	0.72	—	—
[illegible]	1.68	0.70	—	—

Since ascorbic acid is lost so rapidly when exposed to air it is essential to prevent such exposure as much as possible during the analysis.

SUMMARY

The ascorbic acid content of cored apples was determined as they were received in September and October, 1942 and was found to range between 1.7 and 4.5 milligrams per 100 grams of apple tissue including the peel.

In general there was a considerable loss of ascorbic acid during the first two months of storage at 0 to 2 degrees C. The average loss during this period amounted to 25.7 per cent of the total ascorbic acid present when received. The apples had lost an average of 27.5 per cent of their ascorbic acid after four months of storage.

Considerable sample variation was noted hence it was impossible to draw close comparisons between the various apples. Samples of coreless apple tissue including the peel contained from 1.2 to 1.9 times as much ascorbic acid as similar samples without the peel.

During storage the ascorbic acid was lost more rapidly from the skin portion than it was from the flesh. At the end of the 4-month storage period the radial samples including the peel contained about 1.3 times as much ascorbic acid as similar samples without the peel.

Ascorbic acid was lost rapidly from ground tissue on exposure to air. Such exposure must be kept at a minimum during analysis.

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Variations in Blossom Hardiness Within a Hardy Group of Peaches

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PROBLEMS of sampling perplex workers in arboreta and plant introduction gardens as gravely as they affect those working with cultural experiments. Limitations of space and personnel have frequently necessitated the retention, usually arbitrary, of a very limited number of seedlings of a lot, the balance being discarded; it has been assumed, or hoped, that the homogeneity of the material warranted this procedure. Sometimes, as an alternative, young plants have been distributed widely before they have been tested; this course implies the same assumption of homogeneity.

A limited test of the uniformity of bud hardiness in peach trees grown from a single lot of seed received under circumstances apparently justifying assumption of hardiness was afforded by low temperature (—17 degrees F) experienced at the Plant Introduction Garden at Glenn Dale, Maryland in December, 1942. This temperature was recorded on an official thermometer in the standard shelter near the office. The peach trees were in an orchard located about ¼ mile from the office, and possibly 20 feet higher. Comparisons made at other times on clear, calm nights between the sheltered thermometer and an exposed minimum thermometer, mounted on a metal back and suspended on a tree in this orchard, showed very close correspondence. Whatever the exact temperature in the orchard may have been, the extent of the damage to peach buds is evidence of its severity. Examination made 2 or 3 days after the occurrence of this low temperature indicated damage as extensive as that subsequently found by detailed examination; no other low temperature occurring during the winter could be suspected of contributing to the damage.

Temperature and moisture conditions during the previous autumn had been such that the trees had matured well and little killing back of twigs occurred. The trees considered in this study had been planted 2 and 3 years earlier, close together in contour rows; they had received strip cultivation and applications of a complete fertilizer.

The extent of the injury to the buds was determined by counts made after the buds began to swell; all fruit buds that were swelling were considered as having survived the winter cold. Detailed counts of all, or nearly all, buds on a tree were made whenever any live buds were found; estimates, stated in round numbers, were made in most cases where all fruit buds were definitely dead. Rarely were trees bearing less than 200 buds recorded; in no case are counts based on less than 100 buds reported.

A recapitulation of the counts on 207 varieties and clones is presented in Table I, so arranged as to indicate the extent of injury and the immediate source of the material. Since peach pits and trees have traveled on old caravan routes and modern steamships and the primitive races have become widely spread and extensively mixed, it is not surprising to find occasional cases of hardiness in material coming from regions where that trait is not important. This applies in particular to the single varieties from India and from South Africa showing high cold tolerance in their blossoms. The scarcity of cold-tolerant varieties from western Europe reflects the general homogeneity of the varieties originated in these regions. The variability shown by the material from the Union of Soviet Socialist Republic reflects the great diversity of climates embraced within the boundaries of that nation and probably the diversity of types grown.

TABLE I—SOURCES OF CLONES AND PEACH BUD SURVIVALS FOLLOWING A TEMPERATURE —17 DEGREES F (—27.2 DEGREES C) ON DECEMBER 21, 1942

Immediate Source of Clones	Numbers of Clones With Winter Survival Percentages of											Total Clones Examined (Number)
	0	0.1 to 0.9	1 to 4	5 to 9	10 to 19	20 to 29	30 to 39	40 to 49	50 to 59	60 to 60	70 to 79	
Australia	23	6	7	1	1	—	—	—	—	—	—	38
Belgium	—	—	1	—	—	—	—	—	—	—	—	1
China	2	1	1	1	1	—	—	—	1	—	—	7
England	7	6	3	1	—	—	—	—	—	—	—	17
France	16	11	4	—	1	—	—	—	—	—	—	32
Germany	11	3	2	—	—	—	—	—	—	—	-	16
India	1	1	—	—	—	—	—	1	—	—	—	3
Italy	2	6	—	—	—	—	—	—	—	—	—	8
Jugoslavia	—	1	—	—	—	—	—	—	—	—	—	1
Manchuria	1	—	—	—	—	—	—	—	—	—	—	1
New Zealand	7	—	—	—	—	—	—	—	—	—	—	7
South Africa	2	1	—	1	—	1	—	—	—	—	—	5
U. S. A.	16	7	6	—	1	—	—	—	—	—	—	30
U. S. S. R.	3	6	3	2	—	—	1	—	—	—	—	15
U. S. S. R. (North Caucasus)	—	—	1	—	2	5	4	7	4	2	1	26

In view of the general low level of survival, detailed enumeration of all the varieties studied would scarcely justify the space it would require. Table II, however, sets forth the results of the counts on numerous American varieties and on foreign varieties selected for presentation because of their local importance or because they showed the least injury among the varieties tested from their respective regions.

The notably cold resistant variety from South Africa, conspicuous in Table I, is described in a nursery catalog (Herholdt's) as a special selection of Transvaal Yellow, a yellow fleshed clingstone canning-type peach. The cold-tolerant variety from India is Shalil, P.I. 63850, the progenitor of nema-resistant seedlings; this has been reported by Blake (1) to be tender in freezes following periods of high temperature and from other sources as tender in wood. The Pi peach (P.I. 62602) is an ornamental form, having double flowers that in many cases produce twin fruits; its fruits are white-fleshed, small and of poor quality. Attention is invited to the low cold tolerance shown by Proskauer (P.I. 130980) and Kernechter vom Vorgebirge (P.I. 126989) which have been reported (2, 3, 4, 6, 7) to be unusually hardy in tree and bud. These are predominantly races propagated by seed and though apparently fairly well fixed in other respects they may vary in this. Perhaps our trees are an unfortunate sample. In general, the European varieties that have shown some slight trace, even though

TABLE II—BLOSSOM SURVIVAL IN CERTAIN PEACH VARIETIES AND CLONES DURING THE WINTER AND SPRING OF 1942–1943

P. I. No.	Varieties and Seedlings	Source	Trees (No.)	Buds Surviving Winter as of April 1		Survival of Blossoms April 17†
				Buds Counted (Number)	Live (Per Cent)	
111921	Lewis Cling	Austral.	1	706	7.2	——
129817*	Fripp's Late	Austral.	1	1,358	4.1	——
133913	Golden Queen	Austral.	2	192	15.1	——
55776	Yunnan	China	2	1,659	19.4	——
62602	Pi (Flowering)	China	1	262	52.3	——
88564*	John Rivers	England	1	358	1.7	——
111829	Early Silver	England	1	551	5.1	——
111832	Royal George Cling	England	2	1,890	2.1	——
109902	Bellegarde	France	1	171	2.9	——
131781	Bardou-Job	France	2	1,379	12.5	——
131799	Tardive d'Orleans	France	1	287	4.5	——
126989	Kernechter vom Vorgebirge	Germany	2	136	2.2	——
130980	Proskauer	Germany	2	500	0.0	——
132740	Frau Marie Rudolph	Germany	2	314	1.0	——
63850	Shalil	India	1	715	42.8	——
78545	Giallona di Napoli	Italy	2	773	1.9	——
80129	Carinese	Italy	2	954	1.4	——
133982	Herholdt's Late Cling	S. Afr.	2	1,230	5.7	——
133991	Transvaal Yellow	S. Afr.	1	759	27.5	——
——	Belle	U. S. A.	2	751	3.1	——
——	Bound Brook	U. S. A.	2	1,411	0.8	——
——	Candoka	U. S. A.	1	125	0.0	——
——	Elberta	U. S. A.	2	539	0.0	——
——	Fitzgerald	U. S. A.	1	193	1.6	——
——	Golden East	U. S. A.	2	600	0.0	——
——	Golden Globe	U. S. A.	1	100	0.0	——
——	Greensboro	U. S. A.	1	811	0.9	——
——	Kalhaven	U. S. A.	1	689	0.0	——
——	Krummel's October	U. S. A.	1	263	0.0	——
——	Mayflower	U. S. A.	1	255	0.8	——
——	Pacemaker	U. S. A.	1	435	1.4	——
——	Pioneer	U. S. A.	2	201	3.1	——
——	Primrose	U. S. A.	2	1,061	14.2	——
——	Raritan Rose	U. S. A.	1	712	0.6	——
——	Redhaven	U. S. A.	1	166	1.2	——
——	Red Rose	U. S. A.	1	729	0.0	——
——	Summercrest	U. S. A.	1	200	0.0	——
102705*	Seedling	U. S. S. R.	1	703	31.4	——
117679*	Seedling	U. S. S. R.	2	744	6.3	——
125017*	Sary Oilor	U. S. S. R.	1	712	7.3	——
	Seedlings of P. I. No. 104315 from U. S. S. R.					
——	NC-1 (F-4-16)	U. S. S. R.	2	2,424	72.1	67.0
——	NC-2 (F-4-4)	U. S. S. R.	2	2,361	64.6	64.0
——	NC-3 (F-4-7)	U. S. S. R.	2	2,065	63.5	72.0
——	NC-4 (F-4-6)	U. S. S. R.	2	2,035	56.5	57.0
——	NC-5 (F-4-17)	U. S. S. R.	2	2,571	56.1	78.0
——	NC-6 (F-4-11)	U. S. S. R.	1	1,012	51.1	64.0
——	NC-7 (F-4-32)	U. S. S. R.	2	2,127	50.4	36.0
——	NC-8 (F-4-8)	U. S. S. R.	2	2,147	49.1	31.0
——	NC-9 (F-4-35)	U. S. S. R.	2	1,854	47.1	52.0
——	NC-10 (F-4-36)	U. S. S. R.	2	2,269	42.6	55.0
——	NC-11 (F-4-3)	U. S. S. R.	2	2,278	42.3	74.0
——	NC-12 (F-3-128)	U. S. S. R.	2	2,492	41.4	39.0
——	NC-13 (F-4-31)	U. S. S. R.	2	2,162	40.7	30.0
——	NC-14 (F-4-33)	U. S. S. R.	2	1,950	40.1	60.0
——	NC-15 (F-4-19)	U. S. S. R.	2	2,612	35.7	59.0
——	NC-16 (F-4-10)	U. S. S. R.	2	1,994	33.0	62.0
——	NC-17 (F-3-129)	U. S. S. R.	2	2,506	31.4	72.0
——	NC-18 (F-4-1)	U. S. S. R.	2	2,333	30.8	64.0
——	NC-19 (F-4-18)	U. S. S. R.	2	2,082	26.8	60.0
——	NC-20 (F-4-2)	U. S. S. R.	2	2,213	24.9	61.0
——	NC-21 (F-4-25)	U. S. S. R.	2	1,960	24.4	53.0
——	NC-22 (F-4-13)	U. S. S. R.	2	1,790	21.6	66.0
——	NC-23 (F-4-15)	U. S. S. R.	2	2,170	20.4	80.0
——	NC-24 (F-3-120)	U. S. S. R.	2	1,945	18.9	70.0
——	NC-25 (F-4-12)	U. S. S. R.	2	1,907	18.7	72.0
——	NC-26 (F-3-130)	U. S. S. R.	2	2,327	2.5	68.0

*Nectarines.

†Calculated on basis of blossoms uninjured April 1.

small, of cold tolerance, seem not to be those best known or most generally grown; there is no evidence here that selection in Europe has considered cold tolerance of the buds.

The lot reported as P. I. 104,315 comprises clones grown from a lot of seed received in February, 1934, from the Institute of Plant Industry at Leningrad, Union of Soviet Socialist Republics, as collected at the northern limit of peach cultivation in the northern Caucasus region. No further information of the origin or nature of this material is available. The seedlings fruiting at the Plant Introduction Garden at Chico, California, showed striking homogeneity in fruit characteristics, the fruits being uniformly white-fleshed, freestone, rather flat, medium to small and medium to poor in quality. After some seedlings producing the most inferior fruits had been discarded, the remainder were propagated and two trees of each clone were planted in the orchard at Glenn Dale, Maryland to await a test winter.

In contrast to the paucity of blossom-hardy types in most regions, the general showing made by the clones from the North Caucasus seed is conspicuous. Before this group is discussed in detail, however, its general resistance to spring frosts, as well as to the early winter freeze should be noted, since this may give some indication of the potentialities of this group in resisting freezes occurring in late winter, following periods of relatively high temperature.

In this group the blossoms that had survived the winter were well enough advanced to be seen from some distance on April 5 and were ready to open with about two days of moderately warm weather. Minimum temperatures of 18, 17, 18, 23, and 19 degrees F were recorded on April 4, 6, 7, 15, and 16 respectively; during this period most uninjured blossoms opened. Unfortunately the winter killing of the blossoms of standard varieties had been so complete that no varietal comparisons of spring tolerance were possible. Since, however, Scott and Cullinan (5) report extensive injury to open peach blossoms at 23.5 degrees F the fact that the survival figures reported here were taken after the blossoms had been exposed to 19 degrees F on the 16th when most of them were open, seems to indicate a considerable degree of tolerance to spring frosts, and inferentially to freezes occurring in late winter, after some warm weather. This line of peaches, then, seems to have rather notable blossom hardiness whether measured by northern or by southern standards.

With the general hardiness of the North Caucasus group well established, it is profitable to turn to consideration of the winter hardiness of the individual clones of which it is composed. Since the seed from which they were grown was reported to have come from the northern limit of peach production, it appears logical to expect that the seedlings would be uniform in hardiness above other characteristics. In view of the uniformity of the lot in fruit and tree characteristics, it is rather surprising — and important to breeders — to find a distribution in bud survival that suggests a normal frequency curve, with a high mean, but extending its lower limit into the tenderness characteristic of the standard varieties of western Europe and the United States.

It is, of course, probable that even the least hardy clones of this

North Caucasus group carry genes for hardiness, but it seems likely that breeders seeking hardiness would prefer, other things equal, to breed from the most hardy, rather than the least hardy, individuals of a group. A breeding program in fruits involves so much in time and labor and space that its foundation material deserves closest scrutiny. The results reported here indicate rather definitely that mere geographic source, though significant and important, is not a guarantee of possession of all the attributes it might seem to imply. They point also to the possible loss involved in planting one or two trees out of a group of seedlings in an arboretum and considering it to represent a race physiologically as well as taxonomically (8). They point further to the peril involved in using material thus "selected"— in effect at random — as the foundation of a breeding program and to the need of comprehensive testing and selection of introduced material prior to the start of breeding.

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Seasonal Changes in the Juice of the Calamondin in Florida

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THE calamondin (*Citrus mitis* Blanco) produces a pleasantly flavored acid fruit. The tree is medium in size, hardy, and prolific, and it thrives well in Florida over a wide range of soil and climatic conditions. Hume (4) states that the calamondin is a "native in the Philippine Islands, whence it was introduced into Panama and from there into the United States. It is very hardy; in fact, it may be the hardiest of the edible citrus species now growing in the citrus districts of the United States. The calamondin is a valuable fruit for the same use as limes . . . fruit small (1 to 1½ inches in diameter), subglobose, apex depressed, bright reddish orange in color . . . loose, thin rind; pulp very acid, of good flavor; seeds usually 2 to 5, small; cotyledons green . . ."

The hardiness, prolificness, and adaptability of the tree to a wide environmental range suggest its possible value as breeding stock. Its principal ripening season in peninsular Florida, from mid-fall to mid-spring, when limes, lemons, or other acid citrus fruits are not ripening in quantity, makes it a desirable fruit in that area, especially for domestic use in flavoring drinks, fish, pastries, and so on, and the rind oil is non-irritating to the lips and mucous membrane of the mouth. The glucoside flavor so commonly encountered in the pulp and rind of many citrus fruits is rarely present in objectionable amounts in the calamondin. The fruit is eaten, pulp and rind, the same as the kumquat, by those who enjoy acid citrus fruits.

Stahl (7) analyzed 16 types of acid citrus and found that the juice of the Key lime contained the highest acid and lowest total sugars, while the calamondin and the Sperryola lemon contained the lowest acid, averaging the same in both.

In Florida the calamondin (Fig. 1) is rarely found in plantings of more than one or sometimes two trees, usually in dooryards; yet tree owners value the fruit as one that may be used in lieu of other acid citrus.

The seasonal changes in the calamondin have recently been followed during ripening. Although only a few trees were available as a source of fruit, it is believed that these trees and fruit were typical since no significant variation has been observed in the habit of tree growth or physical characteristics of the fruit, regardless of the tree's location. It is also believed that the physical and chemical characteristics presented here are in harmony with those of Florida calamondins as a class. Doubtless slight variations from tree to tree do exist; yet they are apparently not of sufficient magnitude to seriously distort the curve for seasonal trends because a comparison with the data of other workers indicates that the values reported here are typical of calamondins in general.

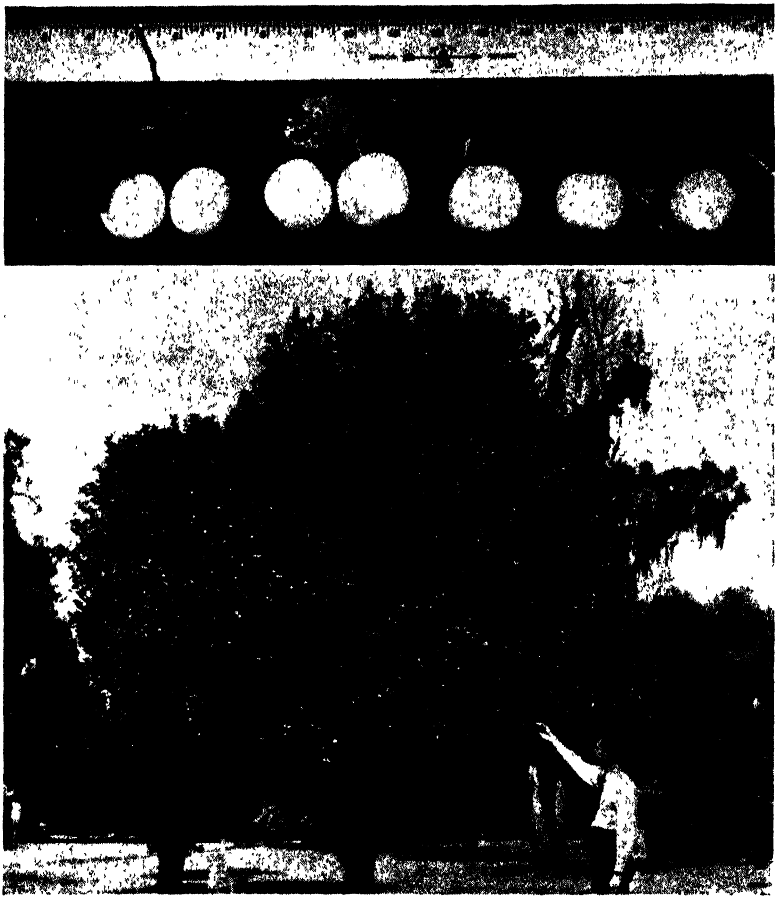

FIG. 1. Calamondin fruit and tree, Polk County, Florida.

MATERIAL AND METHODS

The trees used in these tests were a seedling calamondin (tree A, Table I) growing on the United States Horticultural Station grounds at Orlando, Florida, (1937–39); another budded on rough lemon rootstock (tree B) growing about 7 miles northwest of Orlando (1941–42); and still another on rough lemon rootstock (tree C) growing about 14 miles west of Orlando (1941–42). Each tree was about 15 years old, in good general condition, and bore heavy crops.

Samples of from 40 to 75 fairly uniform fruits were gathered from the outer branches at intervals usually of four or more weeks during the season, brought to the laboratory and culled to remove extreme sizes. Twenty-five fruits from the seedling tree and 50 from the budded trees were analyzed at each picking. Rind color was determined by means of a color chart prepared by Bureau of Plant Industry artists, while juice color was compared with color plates in the "Dictionary of Color," Maerz & Paul, 1st Edition, 1930. The fruit was halved, the juice extracted by finger pressure, composited, and filtered through cheesecloth, and total soluble solids were determined by the use of a Brix spindle. Total acid, hydrogen-ion concentration (pH), and ascorbic acid were determined by the procedure followed by Harding, Winston, and Fisher (2). The chemical and physical properties observed are shown in Table I and Fig. 2.

TABLE I—SEASONAL CHANGES IN SOME CONSTITUENTS OF THE JUICE OF FLORIDA CALAMONDINS AND IN RIND COLOR (1936 TO 1942)

Tree	Date	Total Soluble Solids (Per Cent)	Acid (Per Cent)	S/A Ratio	Active Acidity (pH)	Ascorbic Acid (Mg./ml)	Color	
							Rind*	Juice†
1936–37								
A	Dec 12, 1936	9.80	6.12	1.60	—	0.35	O	10L8
A	Jan 9, 1937	12.21	6.41	1.90	—	0.34	T	—
A	Jan 23, 1937	13.04	6.81	1.91	—	0.33	T	—
A	Apr 26, 1937	14.18	7.47	1.90	2.20	0.30	TF	—
1937–38								
A	Oct 29, 1937	8.36	6.63	1.26	2.30	0.33	YG	10L7
A	Dec 17, 1937	9.68	6.06	1.60	2.41	0.34	O	10L8
A	Feb 17, 1938	11.33	6.97	1.63	2.33	0.33	T	10L9
A	Mar 18, 1938	12.62	8.10	1.56	2.35	0.25	T	10L9
1941–42								
B	Dec 10, 1941	9.76	5.73	1.70	2.31	0.36	O	9L7
B	Jan 7, 1942	9.98	5.56	1.79	2.42	0.36	T	9L7
B	Feb 4, 1942	11.47	5.63	2.04	2.32	0.37	T	9L7
B	Mar 4, 1942	12.38	6.13	2.02	2.29	0.39	TF	10K9
B	Mar 31, 1942	13.61	6.34	2.15	2.28	0.41	TF	10K9
B	Apr 25, 1942	13.89	5.90	2.35	2.40	0.38	TF	10K9
1941–42								
C	Dec 17, 1941	10.51	4.89	2.15	2.38	0.34	O	9L7
C	Jan 7, 1942	10.37	5.18	2.00	2.30	0.35	T	9L7
C	Feb 4, 1942	11.87	4.91	2.42	2.29	0.34	T	9L7
C	Mar 4, 1942	13.23	5.42	2.44	2.29	0.38	TF	10L9
C	Mar 31, 1942	13.99	5.55	2.52	2.19	0.38	TF	10L9
C	Apr 25, 1942	13.32	5.14	2.59	2.31	0.38	TF	10L9

*Rind Color: YG—Yellowish green; O—orange; T—tangerine; TF—tangerine, faded on exposed cheek.

†See plates 9 and 10, Dictionary of Color, Maerz and Paul, 1st Ed., 1930.

SEASONAL CHANGES IN FRUIT CHARACTERS

The data show that total soluble solids increased with advancing maturity. The range was from 9.68 to 10.51 per cent in December to 12.62 to 13.99 per cent in March. At the April sampling the increment in soluble solids had lessened for tree B, and there was a decrease in the solids of fruit from tree C. By this time the fruit was overripe and many were drying out.

Total acid, ranging from 4.89 to 6.12 per cent in December, increased very gradually to a range of 5.55 to 8.10 per cent in March. In the April samples from both trees on rough lemon (trees B and C) the acid had dropped slightly, as is usual with juice of fruit in an advanced stage of maturity.

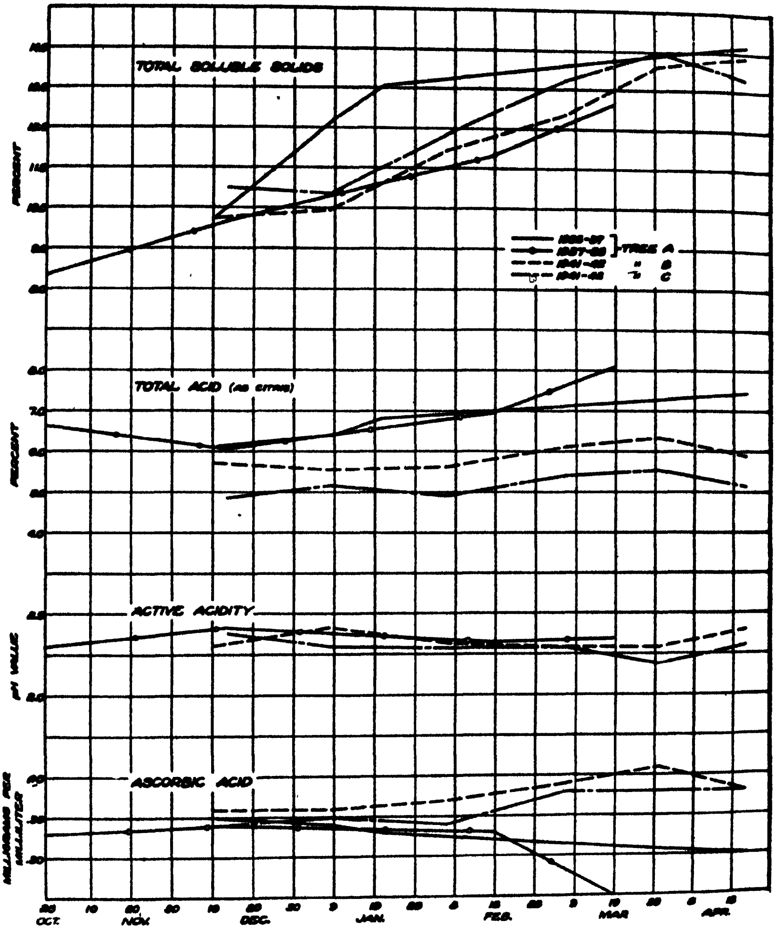

FIG. 2. Seasonal trends in the chemical composition of the calamondin.

During the period of observation there was a more rapid increase in total soluble solids than in total acid, and this resulted in a slight increase in the solids-to-acid ratio.

The pH of samples from tree A decreased between December and March, at which date collection of samples from this tree were discontinued. Similarly pH values for the samples from trees B and C lessened during the same time, but this was followed by an increase in the April sample.

The ascorbic acid content of the juice of the fruit from tree A decreased during the first season from .35 mg/ml in December to .30 mg/ml in April. During the second season the ascorbic acid content decreased from .33 mg/ml in October to .25 mg/ml in March, over periods of 134 and 140 days, respectively; whereas, in the case of fruit from trees B and C, respectively, it increased from .36 and .34 mg/ml in December to .41 and .38 mg/ml in March. In April the ascorbic acid in fruit from tree B decreased slightly while this constituent remained constant in fruit from tree C.

The rind color of the fruit harvested in late October was a yellowish green. By December it had attained an orange color; in January it was a tangerine color; and in February there was a considerable loss in pigment, especially on the exposed cheek. Such changes are commonly observed in tangerines and the deeper colored oranges.

Juice color deepened as the season advanced, gradually changing from about 9–L–7 ("Dictionary of Color," Maerz & Paul) early in the season to 10–L–9 toward the end of the season, thus suggesting an increase in total carotenoid pigments.

Heavy dropping of the fruit, which probably affected the uniformity of the sample, occurred on several occasions following rainy periods, when Penicillium rot attacked especially the larger and probably more mature fruit on the tree.

The increase in total soluble solids was quite consistent and their quantitative values were approximately those commonly observed in oranges; however, in the case of calamondins, a part of the increase must be attributed to increment of acid rather than sugar. In the last sample from tree C there was a slight drop in total soluble solids, doubtless due to over maturity.

The greater amount of acid in fruit from the seedling calamondin than in fruit from trees on rough lemon rootstock is in harmony with results previously reported for oranges and other citrus fruits (2, 3) when similar comparisons were made. The gradual increase in total acid of the calamondin is of interest since the acidity of most fruits decreases during the ripening process. Traub and Robinson (8) have shown that the total acid in Key limes remains fairly constant during the shipping season. Their results with Florida grown Eureka, Meyer, and Perrine lemons were not so consistent, but there may have been a slight upward trend in total acid in the latter two.

Lynch (5) in studying the seasonal changes in the Persian lime found that the juice acidity remained constant and the soluble solids declined slightly during the sampling period. The fruit reached maturity in from 125 to 140 days after blossoming.

It is worthy of comment that the Key lime abscises very soon after it becomes edible; whereas, the Persian (or Tahiti) lime and the Perrine lemon remain on the tree and retain their juice quality for a longer period. These characteristics are still more pronounced in the calamondin. Because the calamondin remains in good condition on the tree longer than other acid citrus, it may have afforded a better opportunity to observe gradual increases in acid content.

It is interesting to note the downward trend in ascorbic acid content in the fruit from tree A and the upward trend in that from trees B and C. Tree A was located in a densely planted plot and was therefore subjected to reduced light intensity while trees B and C stood in the open and were not so influenced. It has been shown by Roy and Bahrt (6), Fudge and Fehmerling (1), and others (2) that fertilizer practices and rootstock and shade influence the ascorbic acid content of citrus juices. Reduced light intensity or shade in this particular case seems to be the more probable cause of the difference noted.

The mild flavor was no more than pleasantly sour throughout the season, apparently due not to a lack of acid but rather to the presence of a considerably greater amount of soluble solids than is found in Persian limes or commercial lemons, as is shown in Table II, which gives data on the juice composition of the principal acid citrus fruits grown in Florida for use as fresh fruit. The samples were harvested when the fruit was commercially mature or "ripe".

TABLE II—CHEMICAL CHARACTERISTICS OF SOME FLORIDA ACID CITRUS FRUITS WHEN COMMERCIALLY MATURE

Type and Variety	Source	No. Lots	Avg. No. Fruit	Determination:	Acid		Total Soluble Solids (Per Cent)	Solids Less Acid	Ascorbic Acid (Mg/ml)
					Total (Per Cent)	Active (pH)			
Key lime*	Florida Keys	20	48	Range	7.41–9.98	2.07–2.48	8 12–11.52	—	30–.48
				Average	8.19		9.23	1.04	.374
Persian lime	Polk and Highlands Counties	10	46	Range	5.41–6.38	2.06–2.46	6 80–9.26	—	.22–.37
				Average	5 91		7.73	1.82	.296
Perrine lemon	Highlands County	10	45	Range	6.72–7.95	2.10–2.61	7.80–9.46	—	.19–.33
				Average	7.11		8.58	1.47	.255
Villa Franca lemon	Orange County	10	41	Range	5.66–6.77	2.09–2.57	7.67–8.86	—	.33–.50
				Average	6.35		8.23	1.88	438
Calamondin	Orange County	20	47	Range	4.89–8.10	2.19–2.42	8.36–14.18	—	.25–.41
				Average	6.05		11.83	5.78	.350

*Data on calamondin covers three seasons, while other data were gathered during two seasons only.

It is interesting to observe that the difference between soluble solids and total acid was least in the Key lime, the most sour fruit, and that the greatest difference between soluble solids and total acid was noted in the calamondin, which is least sour. In these species the average of the pH values was also lowest in the juice of the Key lime, 2.20, and slightly higher in the calamondin, 2.32.

In considering the tartness of the two, the difference in pH value alone hardly accounts for the unlikeness in palatability, since there are five times more soluble solids (other than acids) in the calamondin than in the Key lime. The solids referred to here are undoubtedly mostly sugars.

The acid content as well as the soluble-solids-less-acid content of the Perrine lemon, a lemon-Key lime hybrid, falls approximately midway between that of the Villa Franca lemon and the Key lime.

SUMMARY

The calamondin is one of the hardiest citrus species, and the hardiest of all the edible acid citrus grown in Florida, where it thrives well throughout peninsular Florida. Although it is very prolific, rarely are more than one or two trees found in a planting. The fruit, about an inch in diameter, and easily "juiced", has a season from late fall to midspring when the more common acid citrus fruits are out of season. It is an excellent substitute for limes or lemons.

The rind color changes from deep green in early fall through orange to tangerine in winter.

The total soluble solids, total acid, and, under certain conditions, the ascorbic acid (vitamin C) content of the calamondin increase with advancing maturity.

Juice color deepens from orange to deep orange or tangerine as the season advances.

The flavor is pleasantly acid and the fruit can be eaten whole like a kumquat. The rind oils are not irritating to the mucous membrane of the mouth.

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Seasonal Trend of Fruit-Bud Hardiness in Peaches

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POMOLOGISTS over a period of years have noted that seasonal variations in cold hardiness occur within different varieties of the peach (*Prunus persica* Batsch.), particularly in regions where the winter temperatures fluctuate markedly. To measure such variations in hardiness, some means of simulating winter temperature changes is necessary. Apparatus for controlled artificial freezing of peach buds has been designed and a satisfactory method for rating the fruit-bud hardiness of varieties has been established by earlier work of the authors (7, 8). This preliminary work has made possible a study of the seasonal trend of the cold hardiness of peach fruit buds in New Jersey. Results of such a study for the winter of 1941–42 at New Brunswick, New Jersey are presented herein.

Cullinan and Weinberger (4) froze buds of the peach in a chamber with thermostatic control for the desired minimum temperatures, but experienced difficulty in lowering the temperature at a predetermined rate on successive dates. Chandler (3) has shown that the rate of fall to a given critical minimum temperature is particularly important in determining the amount of injury to peach buds and, moreover, that the amount of injury is not influenced by differing rates of thawing the buds. Hence the temperature at which injury occurred was used by Cullinan and Weinberger as a criterion of cold hardiness at a particular time. Their results indicated that near Washington, D. C., Elberta buds increased in cold resistance during November, changed little during December, and reached the maximum observed resistance on January 21, 1933. Following this date, buds were less resistant to cold. Fruit-buds of Greensboro and Carman were consistently hardier than those of Elberta.

In studies with tung, *Aleurites fordii* Hemsl., Fernholz and Potter (5) determined the seasonal trend of hardiness by artificial freezing of tissues on 14 dates throughout the season. Minimum temperatures that gave equivalent amounts of injury on different dates were used to indicate that hardiness trend. They found that tung increased in cold resistance from the time of leaf fall to midwinter. Maximum cold resistance occurred simultaneously with the lowest minimum temperatures. With the approach of spring, hardiness decreased rapidly.

Experimental Methods and Materials

A Frigidaire ice-cream cabinet, Model U-5A, supplemented with additional equipment which made possible either fast or slow rates of

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cooling was used to freeze peach buds. The rates of cooling (approximately 2 to 3 degrees F change per hour) were obtained by use of a tank of 50 per cent alcohol in the refrigerator. This solution cooled more slowly than air in the compartment, and resulted in slow cooling of samples sealed within weighted test tubes (1¼ by 12 inches) which were stoppered and placed in the bath. A vacuum-operated stirrer agitated the bath and maintained an even temperature throughout the solution. A continuous temperature record of the solution was made by a recording thermometer which had its remote extension bulb inserted in the bath. A complete description of the apparatus with illustrations has been published elsewhere (8).

Since the rate of fall to a given minimum temperature could be readily duplicated in this apparatus, a different approach to determining the seasonal trend of hardiness from that of other workers was used in these investigations. The rate of fall which would kill most of the buds was determined by preliminary tests in the late fall of 1941. Then this same rate of fall, to a temperature of —8 degrees F, was duplicated on each successive date on which samples were frozen. Any change in fruit-bud hardiness on a certain date would be reflected in the percentage of live buds in the samples tested — that is, with an increase in hardiness fewer buds would be injured. The rate of fall from 36 degrees F to —8 degrees F is shown in Fig. 1. A starting-temperature of 36 degrees F was used in each test. When the temperature of the bath reached —6 degrees, one-half of the samples were removed. The remainder were allowed to cool to —8 degrees F. After removal from the refrigerator, the sealed tubes were left at room temperature until all frost, which had formed copiously on the twigs within had melted, the twigs were then removed and stood in pans of water.

Samples of the varieties used were obtained from the commercial orchard of H. M. Adams, Franklin Park, which is about 8 miles from New Brunswick, New Jersey. The sample twigs were of two lengths, closely approximating 12 inches and 18 inches, respectively, and had an optimum number of fruit buds per twig. They were collected between 2:00 and 4:00 p.m. on each date by selecting one or two twigs of each length from each of 20 trees. The twigs were brought immediately to the laboratory, randomized into lots of 10 to 12 twigs, cut to proper length to accommodate them to the tubes, and sealed therein ready for freezing by 5:30 p.m. Twenty-four to 48 hours after thawing, the number of living buds and those which had been killed on each 12-inch and 18-inch twig was recorded. Variation in the percentage of uninjured buds on different twigs occurred. Chi-square values were determined according to methods of Snedecor (9) to test the homogeneity of the varietal samples. The data for the 12-inch and 18-inch samples of each variety were pooled; several twigs were grouped at random for computing chi-square in R x 2 tables. When only sampling variation from the mean percentage of live buds for a variety resulting from a given treatment on each date had been proved, differences in the percentages of live buds on the successive dates were tested by chi-square calculated in 2 x 2 tables.

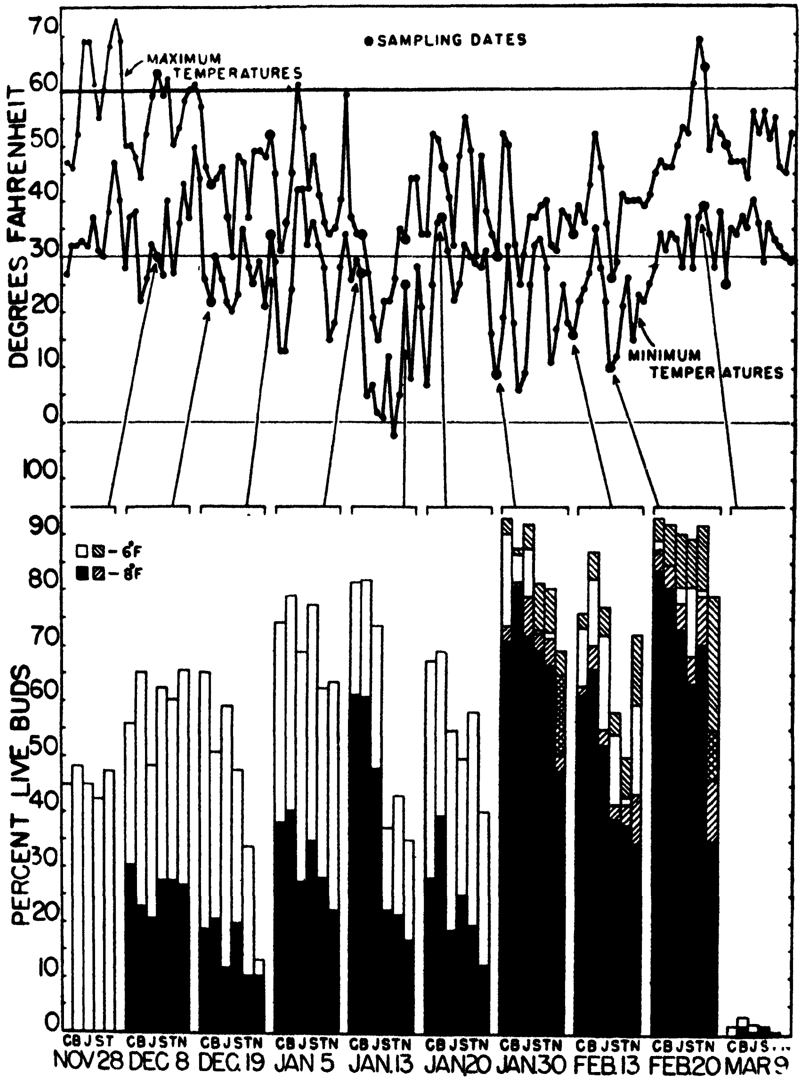

FIG. 1. Above: Daily maximum and minimum temperatures at New Brunswick, N. J., winter of 1941–42. Below: Percentage of live buds for Cumberland (C), Belle (B), Golden Jubilee (J), Summercrest (S), Triogem (T), and N. J. 83 (N) when tested at —6 degrees and —8 degrees F respectively on successive dates during the winter of 1941–42, at New Brunswick, New Jersey; hatchings added to values for the —6 degrees and —8 degrees treatments equal percentages calculated on the basis of all buds that were alive before the freezing tests.

A minimum of —2 degrees F was recorded at the orchard in New Brunswick, New Jersey, on January 11, 1942. No temperature record at Franklin Park, New Jersey, was available for this date, but the minimum there probably was little different from that at New Brunswick. Samples of 200 buds taken directly from the Adams orchard on January 13 had the following percentages of live buds: Cumberland, 96.8; Belle, 96.1; Golden Jubilee, 95.3; Summercrest, 95.4; Triogem, 88.4; and N. J. 83, 69.1. Therefore percentages of live buds, as shown in Fig. 2, and Tables I and II, were calculated in two ways: (a) on the basis of the total number of buds examined in a sample; and (b) on the basis of all live buds before the artificial freezing test — that is, buds that were recognized as having been killed in the orchard were eliminated. The pooled samples of 12-inch and 18-inch twigs had from 200 buds to sometimes 500 buds in the case of Cumberland, which has commonly 30 buds per 12-inch twig.

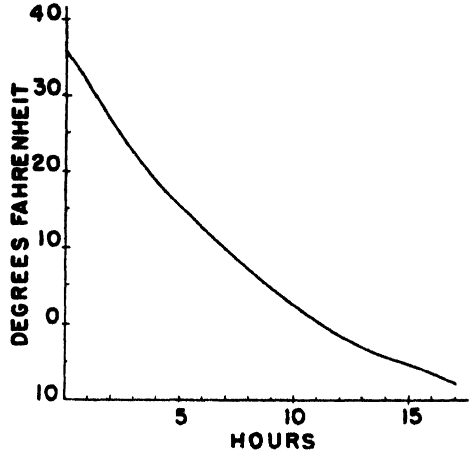

Fig. 2. Rate of cooling in artificial freezing tests.

Discussion and Conclusions

White frosts with minimum temperatures of 27 degrees to 32 degrees F occurred on 13 days in November. However, many garden plants including salvia were not killed until the night of November 21–22. By November 28 most peaches had dropped their leaves; nevertheless Shalil (P. I. 36485) and the Yunnans (P. I. 55776, 55885, 55886)

TABLE I—Percentage of Live Buds for Six Peach Varieties After Freezing to Four Minimum Temperatures at the Same Rate of Cooling on November 28, 1941 and on March 13, 1942

Variety	November 28, 1941				March 13, 1942			
	Minimum Temperature (Degrees F)				Minimum Temperature (Degrees F)			
	2	0	–3	–6	2	0	–3	–6
Cumberland	95.3	96.2	85.6	45.0	75.5* 73.2	57.1 56.0	19.2 18.8	— 1.6
Belle	92.2	91.2	81.7	48.3	77.4 74.2	62.7 60.6	24.6 23.8	— 0.4
Golden Jubilee	96.9	93.2	83.0	45.0	76.7 71.3	59.1 55.2	15.0 14.3	— 0.6
Summercrest	90.3	88.6	83.7	42.5†	61.8 58.1	53.3 49.8	6.7 6.5	— 0.0
Triogem	90.1	87.4	74.4	47.5	57.5 53.2	47.9 41.0	11.0 9.8	— 0.6
N. J. 83	—	—	—	—	66.7 45.2	70.1 53.7	7.8 4.6	— 0.8

*Percentage (top rows of figures) calculated on basis of all live buds before artificial freezing test; some buds were killed by low temperatures in the orchard on January 11, 1942.

†P value in chi-square test for homogeneity less than 5 per cent the buds on 18-inch twigs tending to be hardier than those on 12-inch twigs.

had one-third of their foliage still left on the trees at New Brunswick, New Jersey. There had been sufficient cold weather in late October and early November at New Brunswick, for fruit buds of the varieties tested to have become fairly hardy by November 28, 1941, as judged by the percentages of live buds shown in Table I. On that date, exposure to —6 degrees F left from 42.5 (Summercrest) to 48.3 (Belle) per cent of live buds; but there was no significant difference in the fruit-bud hardiness of the five varieties tested at four minimum temperatures (2, 0, —3, and —6 degrees F).

After freezing weather on December 6 and 7 (Fig. 2), the samples tested at —6 degrees F on December 8 (also see Table II) were hardier than on November 28. Data for tests made on December 19, following a day with above-freezing temperatures, showed that all varieties in the —8 degrees F treatment and the relatively more tender varieties, especially N. J. 83, in the —6 degrees F treatment were less hardy than on December 8. However, Cumberland and Golden Jubilee in the —6 degrees F treatment seemed to gain in hardiness. On January 5, 1942, all varieties showed increased hardiness for both treatments

TABLE II—PERCENTAGES OF LIVE FRUIT BUDS FOR SIX PEACH VARIETIES; TWIGS WERE COLLECTED ON THE SUCCESSIVE DATES AND SUBJECTED TO FREEZING AT —6 DEGREES AND —8 DEGREES F*

Variety	Sampling Dates 1941–42										
	Nov 28	Dec 8	Dec 19	Jan 5	Jan 13	Jan 20	Jan 30	Feb 13	Feb 20	Mar 9	Mar 13
	Samples Removed at –6 Degrees F										
Cumberland	45.0	56.1	65.3	74.2	81.3	67.4	(93.0)† 90.4	(76.0) 73.5	(93.1) 89.2	1.6	1.6
Belle	48.3	65.1	50.8	78.9	81.9	69.2	(87.4) 81.6	87.1 82.3	91.9 84.9	3.1	0.4
Golden Jubilee	45.0	48.7	59.3	69.1	73.6	55.1	92.1 87.4	77.1 72.3	90.3 80.7	1.7	0.6
Summercrest	42.5‡	62.5	47.6	77.4	37.5	50.0	81.6 72.9	58.3 54.2	89.2 80.8	1.3	0.0
Triogem	47.5	60.6	34.0	62.7	43.1	58.3‡	80.6 72.4	50.3 42.9	91.7 80.2	0.3	0.6
N. J. 83	—	65.7	13.3	63.5	35.2	40.3	65.1 50.6	72.2 59.7	79.0‡ 46.2	0.0	0.8
	Samples Removed at –8 Degrees F										
Cumberland	—	30.5	17.8	38.4‡	61.3	27.8	73.8 71.0	62.7 61.4	87.5 83.7	0.0	—
Belle	—	22.8	20.7‡	40.3	61.0	39.5	86.5 80.7	70.2 66.0	84.8 81.4	1.5	—
Golden Jubilee	—	20.8	11.7	27.6	47.9	18.9	77.9 72.0	55.0 52.4	77.9 73.0	0.4	—
Summercrest	—	27.6	20.0	35.0	22.7	25.3	72.5 69.3	41.4‡ 39.4‡	68.2 63.2	1.7	—
Triogem	—	27.5	10.3	28.1	21.8	19.5‡	71.8 67.6	41.6‡ 37.9‡	79.3 70.3	0.3	—
N. J. 83	—	26.9	10.3	22.5	17.0	12.3‡	69.5 47.7	43.5‡ 34.7‡	55.0 35.0	0.0	—

*P value for chi-square test less than 5 per cent when percentage difference between dates for a variety was as much as 7.1 and less than 1 per cent when difference was as much as 11.1; the following exceptions to be noted: 8.9 percentage difference for Cumberland between December 19 and January 5; and 6.3 for Triogem between January 5 and January 13 had P values less than 1 per cent; and 11.5 percentage difference for N. J. 83 between February 13 and February 20 (top rows of figures) had P value greater than 5 per cent.

†Percentages (top rows of figures) calculated on basis of all live buds before freezing test; some buds were killed by low temperatures in the orchard on January 11, 1942.

‡P value in chi-square test for homogeneity less than 5 per cent; the buds on 18-inch twigs tending to be hardier than those on 12-inch twigs in most of these cases.

(—6 and —8 degrees F) over the low level of December 19, 1941, but the less hardy varieties, Summercrest, Triogem, and N. J. 83, did not exceed their hardiness level of December 8, 1941. Differences of 5 or 6 in percentage of live buds did not prove statistically significant when tested by chi-square (see Table II). The lowest daily minimum (—2 degrees F) of the winter on January 11, 1942, clearly showed that fruit buds of Triogem and N. J. 83 were relatively more tender than those of the other varieties, but Summercrest had as many live buds as the hardier varieties. When tested on January 13, 1942, Cumberland, Belle, and Golden Jubilee showed slight gains in bud hardiness for the —6 degrees F treatment, but at the —8 degrees F minimum they showed marked gains over their hardiness level of January 5. On the other hand, Summercrest, Triogem, and N. J. 83 showed losses in hardiness at both temperatures between these two dates. Undoubtedly some buds of the less hardy varieties had been injured in the orchard as a result of the low temperature of January 11.

The artificial-freezing test on January 20 followed a day in which freezing temperatures did not occur in the orchard; the maximum and minimum temperatures for this date being 46 degrees and 37 degrees F respectively (see Fig. 2). Cumberland, Belle, and Golden Jubilee were less hardy for both treatments on this date than on January 13. The less hardy varieties, however, remained virtually unchanged in hardiness at —8 degrees F, but appeared hardier at —6 degrees F. It would seem that in some cases the hardiness of the fruit buds was not adequately tested at —6 degrees F.

Freezing temperatures occurred in the orchard on the 9 days between January 20 and 30. All varieties tested on January 30 showed marked gains in fruit-bud hardiness above the January 20 level, and the highest hardiness level to date for the season was reached. On January 30, it was possible to distinguish buds killed in the orchard from those killed by artificial freezing. The buds injured in the orchard had black shrunken centers and the dead tissues were crisp. In contrast, buds killed by artificial freezing and examined 24 to 48 hours after thawing showed a brown discoloration and had a water-soaked appearance. Two weeks later, on February 13, all varieties were less hardy in the —8 degrees F treatment than on January 30. In the —6 degrees F treatment, Belle remained unchanged, N. J. 83 showed a gain or a loss, depending on which way the percentage of live buds was calculated (orchard-injured buds included in sample in one case and excluded in the other), and other varieties a loss between the dates being compared. It was thought at the time that the peak of hardiness had been reached on January 30 and that a gradual decline of all varieties to a low level of hardiness would result as spring approached. Nevertheless, samples tested on February 20, during a period when out-of-door temperatures fell to 10 degrees F, showed that all varieties had increased in hardiness over their level of February 13 and reached again a level comparable with that of January 30. In the —6 degrees F treatment on February 20, Belle remained virtually unchanged from its hardiness level of February 13 and January 20; N. J. 83 showed a gain or a loss (indicating little actual difference); and the other varieties showed gains to a level comparable to the high resistance of the buds to freezing injury noted on January 30.

The weather in early March (Fig. 2) warmed up gradually until days occurred without freezing temperatures. On March 8 a maximum temperature of 69 degrees F was recorded and freezing did not occur at night. When samples were taken on March 9, buds had swollen considerably, as evidenced by light-green color showing between the bud scales. Until this time the external appearance of the buds remained unchanged. Most of the buds in all varieties were killed in both treatments of the freezing test made on this date. It is probable that the hardiness change during this spring period is not so abrupt as indicated in Fig. 2 and Table II. The picture might have been different if several additional tests had been made during this spring period. In the last test, made on March 13, 1942, when samples were tested at the same four minima as on November 28, 1941, fruit buds of all varieties showed considerable hardiness; for example, Belle showed 62.7 per cent live buds when tested at 0 degree F (see Table I).

The effect of freezing buds to critical low temperatures at a time when relatively high maxima and minima were occurring in the orchard (December 19 and January 20) was quite similar to what happens in orchards when a quick drop to subzero Fahrenheit temperatures occurs immediately after a period of thawing temperatures; that is, more injury results than when the coldest weather has reached the minimum temperatures by gradual cooling over a period of several days.

It seemed apparent from data published elsewhere that hardiness changes in peach fruit buds, as well as other plants, occur within rather short periods of time. After —3 degrees F in the orchard at New Brunswick, New Jersey, on February 13, 1933, Blake (2) reported that Golden Jubilee had 38 per cent live buds. However, the temperatures preceding the —3 degrees F were rather warm. The maxima on February 7, 8, and 9 were 42 degrees, 61 degrees, and 52 degrees F respectively and the minima, 21 degrees, 37 degrees, and 12 degrees F. This undoubtedly resulted in lowered cold resistance. Minus 5 degrees F commonly kills many fruit buds of tender varieties like Elberta, but does not necessarily eliminate the crop.

In studies by Meader, Davidson, and Blake (8), when an average rate of cooling of 2.4 degrees F change per hour (38 degrees F to —7.5 degrees F in 17 hours) was used, Golden Jubilee had 56 per cent live buds in a test made on February 24, 1941. On February 27, 1941, a relatively much slower rate of cooling of 1.2 degrees F change per hour (32 degrees to —15 degrees F in 38 hours) was used. Of the buds of Golden Jubilee, 55 per cent survived —15 degrees F, which is considerably below the minimum of —3 degrees F that left only 38 per cent live buds on this variety in the orchard at New Brunswick, New Jersey. The tests of Golden Jubilee on February 24 and 27, 1941, indicated that similar hardiness ratings can be obtained by using different rates of temperature fall to different minima. Moreover, if no hardiness change in the buds in the orchard from February 24 to 27, 1941, is assumed, the buds of Golden Jubilee actually gained hardiness as a result of prolonged slow cooling. Apparently, peach fruit buds change in their relative hardiness rather soon after marked temperature changes. Angelo (1) found that strawberry plants exposed for 6 days to treatments alternating between 12 hours at 0 degree C and 12 hours at 20 degrees C (68 degrees F), gained hardiness at 0 degree C and lost at 20 degrees C. Likewise, Harvey (6) working with elm seedlings noted hardiness changes within short periods of time.

In this study, data (Fig. 2) show that the maximum resistance of buds to cold coincided with the lowest minima recorded for the winter. This agrees with observations of Fernholz and Potter (5) for tung. However, peach buds were less resistant during periods of mild weather that occurred between the periods of low minimum temperatures than they were at the times when low daily minima were experienced. The seasonal trend of peach fruit-bud hardiness, as determined by artificial freezing tests on 11 dates throughout the winter of 1941–42, tended to be related inversely to the maximum and minimum temperatures at New Brunswick, New Jersey.

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Fruit Setting of the Bruce Plum[1]

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THERE are many varieties of plums which will not produce fruit when pollinated with their own pollen or with pollen of certain other varieties; this characteristic is more pronounced in certain groups than in others. Practically all varieties of the American and Japanese species and their hybrids and many varieties of European species have been found to be self-unfruitful.

The Bruce variety of plum is an American-Japanese hybrid resulting from a cross between *Prunus salicina* (Japanese plum) and *P. angustifolia* (Chickasaw plum) made by Mr. A. L. Bruce of Donley County, Texas, about 1902. It has the size and quality of the Japanese and the hardiness and disease resistance of the Chickasaw. This hybrid is widely believed to be self-unfruitful, but some growers consider it self-fruitful.

Commercial orchards of this variety are relatively few, the largest plantings of pure Bruce orchards being near Grapeland, Texas. There is an estimated acreage of 1,000 acres of Bruce orchards in this vicinity, some blocks being 80 acres or more.

MATERIALS AND PROCEDURE

The main part of this experiment was conducted near Grapeland, Texas, in an 80-acre orchard of 8- to 12-year-old Bruce trees. These trees were healthy and vigorous, and were heavily pruned each winter to an open center system. The soil is a very deep, well drained Norfolk sand or sandy loam.

On a smaller scale, the same experiment was repeated at the horticulture farm of the Texas A. and M. College at College Station, Texas. These trees were in a mixed orchard, pruned to a modified leader system, and growing in a Lufkin fine sandy loam. In each orchard, a practice of clean cultivation and cover crop system had been given for several years.

The experiment began on February 17, 1942, when screen cages were placed over medium-sized trees and sealed to be insect proof. In some of these, hives of bees were placed as pollinating agents. Checks were used in which no bees were placed. The bees were shut up several days previous to the installation within the cages. Reasonable assurance could be expected against contamination of other pollen because no other varieties were blossoming at this time.

A few branches were bagged with cloth bags until after emasculation to insure against pollination by insects previous to hand pollination. These flowers which were to be hand pollinated, were not bagged in every instance, for Flory (2) found that insects were not attracted to blossoms from which the petals had been removed.

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[1] Taken from a thesis "Factors Influencing Fruit Setting of the Bruce Plum in Texas", presented by the author in partial fulfillment of the requirements for a Master of Science degree at the Texas Agricultural and Mechanical College.

Each of four treatments were duplicated in the whole-tree experiments, as follows: (a) Two Bruce trees were caged separately in each of which was placed a hive of bees. This necessitated the fertilization with its own pollen, if fruit be set. These were given numbers of A-1 and A-2. (b) Two trees were caged separately in each of which was supplied a hive of bees and bouquets of the Chickasaw plum (*Prunus angustifolia*). These bouquets were changed every other day to assure freshness and viability of pollen. These trees were designated as B-1 and B-2. (c) Two trees were caged separately in which neither pollinating agents nor bouquets were placed. This was primarily a check to insure the necessity of bees or some agent of pollination other than wind. These were labeled C-1 and C-2. (d) Two trees were left under normal orchard conditions as checks. These were labeled D-1 and D-2. The blossoms were counted on each tree so the percentage of fruit set could be determined.

An hygrograph and a thermograph was set up in the middle of the orchard and remained there throughout the entire blossoming period. Daily notes on weather conditions and insect activity were also kept.

PRESENTATION OF DATA

Insect activity, particularly that of bees, was greatly retarded, and in many cases, completely inhibited by unfavorable weather conditions during the period of blossoming. Bees were not seen in the orchard when the temperature was lower than 50 degrees F. Very little activity occurred when the relative humidity was above 75 per cent. Cloudiness greatly retarded the flight of bees, and rain or mist completely stopped it. If the wind was high, little or no work was done by insects, unless other conditions were very favorable.

The blossoming period of this experiment was 27 days, of which 20 were cloudy or partly so. High wind prevailed over half the time the trees were in blossom. Rain or mist fell on 8 different days and snow on 2.

The per cent of blossoms which set fruit per tree is given in Table I. Results of hand pollinations are set forth in Table II.

TABLE I—SET OF FRUIT ON SCREENED TREES OF BRUCE PLUM

Tree Number	Blossoms Per Tree (Number)	Fruit Set Per Tree Apr. 20 (Number)	Blossoms Setting Fruit (Per Cent)
A-1	13,019	0	0.0
A-2	15,318	0	0.0
B-1	21,915	477	2.13
B-2	16,468	308	1.26
C-1	14,873	0	0.0
C-2	12,471	0	0.0
D-1	12,561	1049	8.35
D-2	13,620	481	3.55

TABLE II—SET OF FRUIT ON HAND-POLLINATED BLOSSOMS OF BRUCE PLUM

Pollen	Blossoms Pollinated (Number)	Fruit Set (Number)	Blossoms Setting Fruit (Per Cent)
Bruce Plum.....	425	0	0.0
P. angustifolia...	265	23	8.68

Viability of the pollen when germinated on sugar-agar plates, was 53 per cent for Bruce plum and 90 per cent for *Prunus angustifolia.* These are high percentages; however, pollen of *P. angustifolia* is usually high in viability.

SUMMARY AND CONCLUSIONS

A total of twelve trees was used in four treatments in which the percentage of fruit set was determined under each treatment. Two locations were chosen, one at College Station and the other at Grapeland; the treatments at the latter place were replicated, involving the use of eight trees, as reported in Table I. An effort was made to determine the effect, if any, of location on fruit setting, by using the two widely separated orchards.

Studies of the self-unfruitfulness of the Bruce plum were made by the use of bees placed in large screen cages, each cage enclosing a single tree. A second treatment was the same as the first with the addition of bouquets of the native Chickasaw plum (*P. angustifolia*). The third treatment was that of an enclosed Bruce tree to which neither bees nor bouquets were supplied. As a check, a fourth tree was used, which was in the open orchard.

Weather conditions in general were unfavorable for insect activity during the entire blossoming period. Honey bees placed in the cages did not perform normally, and environmental conditions also were unfavorable for fruit setting. The native insects in the open orchard functioned more normally, to produce an average set of 5.95 per cent at Grapeland and 7.08 per cent at College Station.

No fruit was set on any of the Bruce trees when selfed. This substantiates the statements of Gardener, Bradford, and Hooker (3) that most American-Japanese hybrids are self-sterile, and of Flory (2) that the Bruce has proven to be self-sterile. From the results thus obtained, the Bruce plum apparently must have pollen of some other variety to set fruit. This 80-acre orchard, in which there are no pollenizers, must depend on the pollen from native species (*P. angustifolia*), or (*P. anqustifolia Varions*), or from other orchards containing other varieties. The nearest possible pollinizer is a large grove of native Chickasaws about 800 yards from edge of orchard. However, under Texas conditions plums bloom over a very long period of time, and fewer pollinating varieties may be necessary than would be the case farther north where the blooming season is much shorter. The bees are principally native bees with their habitat being in trees bordering the orchard. These may travel farther than the domesticated honey bees, as observed by Hutson (5) and other workers (7, 6, 4).

The percentage of fruit set at College Station, where only three Bruce trees remained open for native insect pollination, and where other plum varieties were near, was considerably higher than that of the check trees in the Grapeland orchard; the average percentages were 7.08 and 5.95 respectively. These differences may be due to the extent to which the existing insect population was able to bring in outside pollen. These results indicate that the dependence of the Bruce on cross-pollination is so great, that a reduction of the bee population or the destruction of native plums near the orchards may prove very detrimental to normal production. If large blocks of Bruce are to be planted, the placing of bees and compatible varieties within the orchard may be necessary, and is certainly advisable.

Since the Bruce pollen is sufficiently viable for effective pollination, and the pistils are normally fertile, as shown by pollinating with pollen of the native plum, the self-sterility of the Bruce plum may be due to the genetical factors as found in other varieties by Ray (8) and Crane and Brown (1).

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Notes on Variation and Self-Sterility in the Mahaleb Cherry[1]

By LLOYD E. JOLEY, *U. S. Department of Agriculture, Glenn Dale, Md.*

DIVERSITY of results in orchard comparisons of cherry trees on Mahaleb and on Mazzard stocks suggests, in addition to differences in compatibility and in edaphic adaptability, diversity within the Mahaleb and the Mazzard stocks utilized. Candioli (1), Fiori (2), Gramm (3), Hegi (4), Heimann (5), Tukey (7) and Vinogradov (8) have indicated variations, largely morphological, in *Prunus mahaleb*, and in the various lots of Mahaleb grown at the U. S. Plant Introduction Garden, Glenn Dale, Maryland, gathered from a wide range of sources, undoubted morphological variations occur.

The sensitivity of Mahaleb seed to treatment prior to stratification enforces extreme caution in comparisons of germinations and initial vigors based on introduced seed from various sources, but experience with two lots seems to justify belief in the existence of physiological, as well as morphological, differences within this species. One lot (P. I. 134246), obtained from the Park National, Askania-Nova, U.S.S.R., produced very high germination in the field, while in another lot, (P. I. 134366) obtained from the Jardin Botanique de l' Université technique de Delft (Pays Bas), Holland, as collected in the municipal parks of The Hague, and planted in an adjacent row, germination was very low. With the former, germination was so high that the seedlings manifestly suffered from competition; in the latter no competition was conceivable. In the autumn of 1941, at the end of two seasons' growth, the seedlings of Dutch origin were measured and each was duplicated by the nearest seedling of Russian origin conforming to its measurements. Thus was constituted a planting of 42 seedlings, randomized in two rows and planted 5 feet apart in rows 8 feet apart in the autumn of 1941. Measurements of these trees, taken in the autumn of 1942, summarized in Table I, leave little reason to doubt the existence of difference, either in vigor or in transplanting recovery, between the two lots.

TABLE I—SUMMARY OF GROWTH MADE BY 84 PAIRED PRUNUS MAHALEB SEEDLINGS (P. I. 134366 AND P. I. 134246) IN FIRST YEAR AFTER TRANSPLANTING

P. I. Number	Source of Seed	Average Cross-section Area Per Seedling 1941 (Mm^2)	Average Cross-section Area Per Seedling 10–29–42 (Mm^2)	Average 1-year Increase in Cross-section Area Per Seedling (Per Cent)	Pairs in Which Cross-section Area Greater (Number)	Mean Linear Growth 10–29–42 (Cm.)
134366	Holland	79.7	155.4	95.0	4	275.9
134246	U. S. S. R.	79.7	202.4*	154.0	30	375.5*

*Difference significant beyond .001 point.

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[1] The author wishes to acknowledge with thanks the assistance given by Dr. A. H. Tillson in making the 1942 pollinations.

If differences among seedling lines prove great enough to justify special care in producing stocks for cherries, utilization of the best stocks will require either vegetative propagation (as by layering) or isolation of élite seed strains. Since vegetative propagation of stone fruit stocks seems likely to increase peril from virus diseases, selection of the best possible seed sources appears desirable. This will necessitate progeny testing. As a preliminary to thorough testing of this sort, knowledge of the pollination requirements of the Mahaleb is essential. Candioli (1) has noted that the three types of Mahaleb which Fiori (2) considers indigenous to Italy are inter-fertile, but apparently no mention is made regarding their self-fertility. McClintock (6) records that an early attempt was made by southern nurserymen in the United States to raise their own Mahaleb cherry seed from an orchard produced by large scale propagation of a single high-yielding tree. According to McClintock's account this pioneer attempt failed not because of the failure to set fruits but from failure to obtain satisfactory stands of seedlings. He does not give any explanation for this failure. These are the only papers relating to the pollination of the Mahaleb cherry to come to the author's attention.

The pollination study now reported began in the spring of 1942, utilizing the oldest Mahaleb trees available; these were seedlings purchased in 1937 from an American nursery. Three trees were selected for use in the study, but one was soon found to be pollen-sterile and the 1942 study was confined to two trees. The only variation from the technique commonly employed in pollination studies was that occasioned by the recalcitrance of Mahaleb blossoms to being "forced out", necessitating the extraction of pollen very close to the time for opening of the blossoms.

Blossoms used for the cross and self pollinations were bagged shortly before they began to open, and, except for the time necessary to apply pollen, kept bagged until the stigmas began to turn brown and wither. All blossoms pollinated by hand in 1942 were first emasculated, but in 1943 the only blossoms emasculated were those used in making cross pollinations. Blossoms for the 1943 selfing were left in the bags until most of the anthers had dehisced, then brushed over lightly with a camel's hair brush, thus combining pollen gathering and selfing in one operation. Incidental to this it was noted that pollen gathered directly by brushing adhered to the brush much better and was dissipated less rapidly than that collected by first drying the anthers and then storing the pollen in vials. There were, however, variations in the amounts of pollen adhering to the various brushes which, in view of the discovery of a pollen-sterile seedling, indicates a probable variation in pollen production as well.

The results obtained in 1942, shown in Table II, point clearly to the existence of self-sterility in the Mahaleb cherry. The 1943 work conducted on the trees used in 1942 confirmed the first season's work fully. In addition, selfing was done on individuals from several introductions from diverse European sources, viz. Germany, France and Dalmatia. The low sets obtained with selfing on two lots are believed not to be due to accidental contamination, but the results in general

TABLE II—Pollination of Mahaleb Cherry at Glenn Dale, Md.

P. I. Number	Mother Tree	Pollen Parent	1942		1943	
			Number Flowers	Set 6-2-42 (Per Cent)	Number Flowers	Set 5-22-43 (Per Cent)
———	A	B	739	26.1	706	14.7
———	A	Selfed	2766	2.6	1046	1.0
———	A	Bagged	4565	0.1	710	0.8
———	A	Open	5276	21.2	3477	15.3
———	B	A	909	27.8	439	27.3
———	B	Selfed	2384	0.4	1252	0.5
———	B	Bagged	2927	0.1	1046	0.4
———	B	Open	3525	19.5	2648	27.9
125258	CIB48	Selfed	———	———	395	4.3
125258	CIB48	Open	———	———	593	23.8
126528	CIE35	Selfed	———	———	269	4.5
126528	CIE35	Open	———	———	1174	15.8
*	CIA6	Selfed	———	———	946	0.4
*	CIA6	Open	———	———	1460	32.6
125258	CID48	Selfed	———	———	445	0.7
125258	CID48	Open	———	———	1079	21.5
125665	CIE36	Selfed	———	———	146	0 0
125665	CIE36	Open	———	———	557	7.7
125775	CIB3	Selfed	———	———	281	0.0
125775	CIB3	Bagged	———	———	227	0.0
125775	CIB3	Open	———	———	424	36.3
126529	CIB22	Selfed	———	———	584	0.3
126529	CIB22	Open	———	———	1182	12.4

*From commercial seed purchased in the United States.

point to a strong tendency toward self-sterility in the Mahaleb cherry. This, in conjunction with the pollen sterility found in 1942, indicates that if seedlings are to be raised from élite mother trees, attention must be given to pollination and possibly to pollenizers.

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Relation Between Seedling Vigor and Tree Vigor in Apple Hybrids[1]

By M. J. Dorsey and L. F. Hough, *University of Illinois, Urbana, Ill.*

APPLE seedlings vary greatly in vigor. A number of factors affect the vigor of growth and, while no attempt has been made in this instance to evaluate the relative importance of any of them, stress is placed upon the point that growth below a certain minimum is not acceptable. In fruit breeding, therefore, it is necessary to take stock of the well being or growth status of each seedling from time to time as a part of the process of discarding or saving. Since it requires so much space and time to bring apple seedlings into fruiting, it seemed desirable to study the growth response of selected progenies in order to determine what relation there may be between the height during the early years in the nursery or orchard and a later period when the trees may be expected to come into bearing. If it were found that the slow-growing seedlings at the 2-year period, for instance, were also the smaller trees at the nine-year period, the "runts" could be discarded leaving only the more vigorous trees to be set in the orchard for the fruiting tests. If this were done, it would be possible to direct apple breeding more specifically toward applied results by dealing only or primarily with seedling trees possessing the necessary growth.

MATERIAL

Before discussing the data, a statement should be made of the nursery methods followed at the University of Illinois in order to have a picture of the way in which these seedlings have been grown. (a) The seeds were taken from the fruit resulting from the crosses and allowed to dry until stratified about December 1 to 15. At this time a single seed was put in an open bottom wooden planting box or band 2¼ by 2¼ by 5 inches in size. Flats containing 84 planting boxes each were then buried over winter 2 to 4 feet deep. The planting soil used was cut from a sod pile and mixed with one-fifth sand by bulk. In March the flats were removed to cold frames where the seeds germinated. From the cold frames the seedlings were set 1 foot apart in the nursery in May. The first root growth in the nursery, of necessity, therefore, took place mostly downward through the open bottom of the planting box. (b) The seedlings were generally held in the nursery for 2 years, being taken up each fall and stored over winter in a root cellar. In the spring of the third year, the trees were planted in the orchard 15 feet apart each way. The 2-year height record in the tables, therefore, is the height at the end of the second year in the nursery. After the trees were set in the orchard the growth record consisted of measuring the height, spread of top and trunk diameter each fall.

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[1] These data were taken from the records of Project 201, of the University of Illinois Agricultural Experiment Station, which was long under the direction of C. S. Crandall and J. S. Whitmire. The writers acknowledge their indebtedness to both for making this report possible.

METHODS

With this data available for a large number of progenies, it seemed that the relation between the early growth in the nursery and later growth in the orchard could be determined with some assurance. In deciding upon the method of analyzing the data to use, the following exploratory procedure was adopted. Seven progenies with fairly large numbers were selected and all possible simple correlation coefficients were determined between the following variables: (a) The number of days required for the cotyledons to appear above ground after the flats were removed from stratification; (b) height at the first, second and ninth year; (c) trunk diameter at the first, second and ninth year. The coefficients for the variables studied are included in Table I with the exception of those for a, with b and c. For these 42 possible combinations the coefficients of correlation were negative but extremely low (i.e. with only six being above 0.1) in nearly all cases, thus indicating that this relationship could be eliminated with respect to the subject at hand.

By referring to Table I, it will now be seen that on the basis of the degree of correlation and the extent of separation in point of time, r35, r36, r45 and r46 stand out with very little difference between them. On the basis of this evidence, since height is so readily discernible, it was decided to base the analysis of the progenies as a whole upon the correlation between the height at the 2-year and 9-year intervals. The primary factor in the decision rested upon the fact that the time of setting in the orchard after the second year would be the most convenient time for discarding the smaller trees if that proved to be feasible.

It will also be noted in Table I that the multiple correlations are very little higher than the highest simple correlation in each progeny. It will be seen from the partial regression coefficients that both the second year height and the second year trunk diameter may be important in estimating the 9-year trunk diameter, although the second year trunk diameter is usually the better. The first-year height (last column) provides relatively little or no additional help in estimating the 9-year trunk diameter. The correlations between the first and second year growth measurements are not nearly as high as might be expected where such a relatively short time interval has elapsed between measurements. Finally, the correlations between the first year measurements and the ninth year measurements are much lower than those between the second year and ninth year. Nevertheless, nearly all of the coefficients presented in Table I are highly significant statistically.

RESULTS

In arranging the data to bring out the 2-year–9-year relationship the individuals of the 43 selected progenies were entered in correlation tables with the height at the 2-year period as the independent variable and the 9-year height as the dependent variable.

By referring to Table II in which the progenies are arranged according to the descending order of the average 9-year height, it will be seen that the value of *r* is generally low, although statistically significant

TABLE I—CORRELATION COEFFICIENTS BETWEEN FIRST YEAR, SECOND YEAR AND NINTH YEAR GROWTH MEASUREMENTS+ FOR SEVEN HYBRID APPLE PROGENIES

Parentage of Cross	Year of Cross	Number of Trees	Simple Correlation Coefficients for the Relationships Indicated															Multiple§ Correlation Coefficients $R_{6.134}$	Partial Regression‖ Coefficients		
			r_{12}	r_{13}	r_{14}	r_{15}	r_{16}	r_{23}	r_{24}	r_{25}	r_{26}	r_{34}	r_{35}	r_{36}	r_{45}	r_{46}	r_{56}		$\beta_{64.13}$	$\beta_{63.14}$	$\beta_{61.34}$
Rome Beauty × *M. floribunda* (821)	1915	260	.78†	.62†	.58†	.08	.16*	.54†	.52†	.04	.09	.84†	.09	.20†	.12	.26†	.68†	.320†	.314	−.088	.028
Rome Beauty × *M. prunifolia* var. (838)	1914 1915	420	—	.63†	.60†	.00	.27†	—	—	—	—	.84†	.06	.33†	.04	.34†	.66†	.356†	.210	.097	.085
M. baccata (806) × Jonathan‡	1915	215	.79†	.63†	.49†	.14*	.16*	.54†	.51†	.12	.21†	.81†	.39†	.43†	.38†	.43†	.88†	.475†	.235	.353	.177
M. baccata maxima (810) × Duchess	1916	675	.72†	.50†	.41†	.28†	.28†	.38†	.43†	.10*	.24†	.80†	.40†	.43†	.38†	.45†	.93†	.467†	.279	.166	.081
M. microcarpa (19644) × Osimoe	1916	302	.74†	.53†	.44†	.24†	.28†	.44†	.44†	.21†	.21†	.75†	.42†	.41†	.33†	.37†	.89†	.428†	.129	.275	.077
1911-A-4 (Wythe × Winter Rambo) × Winter Rambo	1926	179	.56†	.50†	.28†	.08	.12	.34†	.25†	.02	.09	.72†	.20*	.29†	24†	.36†	.82†	.363†	.312	.067	−.001
M. baccata (807) × Jonathan	1916	284	.59†	.62†	.49†	.17†	.21†	.09	.47†	.23†	.23†	.75†	.29†	.29†	.32†	.32†	.89†	.331†	.243	.078	.043

+The different measurements are indicated according to the following code:

1 = Height at the end of the first year.
3 = Height at the end of the second year.
5 = Height at the end of the ninth year.

2 = Trunk diameter at the end of the first year.
4 = Trunk diameter at the end of the second year.
6 = Trunk diameter at the end of the ninth year.

*Significant.

†Highly significant.

‡The cross and its reciprocal are grouped together since an inspection of their scatter diagrams as well as their statistical constants indicated that they were not markedly different from each other.

§$R_{6.134}$ indicates the correlation of measurement 6 with the combined effect of measurements 1, 3 and 4.

‖$\beta_{64.13}$, when compared with $\beta_{63.14}$ and $\beta_{61.34}$, indicates the proportionate amount of the accounted-for variation in measurement 6 that is due to the association between measurements 6 and 4, independent of the variations resulting from the influence of measurements 1 and 3 on measurement 6.

in 30 progenies [compare these results with Beaumont (1)]. There are, however, interesting differences between the growth rate of the different populations at either end of the 7-year period in question which indicates the influence of genetic factors acting independently of cultural and environmental influences. It is rather surprising to find some seedlings higher at the 2-year period than others within the same progeny at the 9-year period, although this occurs in 27 of the progenies.

Referring to the other constants in Table II, it will be seen first that the standard error of the 9-year height is very large. The fact that the standard error of estimate is nearly as high as the standard error indicates that in nearly all cases there is little or no improvement in our ability to estimate the 9-year height by using the 2-year height.

The data in Table II also shows the variation in height between the progenies. In view of the wide range in growth encountered, it seemed that it would be of interest in answering the question raised in this paper to have available an analysis of the growth in the population as a whole of each 2-year class. To this end the 43 progenies in Table II were thrown together in order to see what would have happened had this material been discarded on some arbitrary height basis.

Suppose 15 inches in height were taken as the minimum height acceptable at the 2-year period and that these seedlings had been discarded on that basis, what would have been included in the lot thus eliminated? It will be noted that in this instance 2,246 seedlings (that is 29.4 per cent) would have been discarded. In order to complete the picture suppose 100 inches in height at the 9-year period were taken as the dividing line between acceptable or non-acceptable vigor. On the basis of these arbitrary limits the following statements can be made: (a) Over half of the seedlings (that is 53.9 per cent) which were below 15 inches in height reached over 100 inches in height by the ninth year. On the other hand 21.3 per cent of the trees which were above 15 inches in height at the second year did not reach the 100-inch class by the ninth year. In other words, discarding the 2,246 trees below 15 inches in height at the 2-year period would have resulted in eliminating 1,210 vigorous trees while getting rid of only 1,036 of the less vigorous ones.

At the same time, in this total population 1,149 non-vigorous trees which came out of the lot above the 15-inch point would have been kept. It should be pointed out that 55.6 per cent of the trees of the total population were over 15 inches in height at 2 years and over 100 inches at 9 years.

Mention should be made of the fact, however, that of those seedlings 30 inches or above at the 2-year period, only 26 were below 100 inches at 9 years while 773 were above this class in height. By referring to Table II it will be seen that some of the progenies, for example, *Malus baccata sanguinea* (813) x Collins, tend to have a larger proportion of vigorous trees than others. This difference suggests a higher genetic level for the growth factors for height in some of the lines of descent.

TABLE II—FREQUENCY DISTRIBUTION OF THE HEIGHT AT TWO YEARS AND THE HEIGHT AT NINE YEARS OF FORTY-THREE HYBRID APPLE PROGENIES

Parentage of Cross§	Year of Cross	Midpoint (Inches) for Two-Year Height Classes													Midpoint (Inches) for Nine-Year Height Classes											Total Number of Trees	Average Height (Inches)		σ		Standard Error of Estimate	r
		2	7	12	17	22	27	32	37	42	47	52	57	62	15	35	55	75	95	115	135	155	175	195	215		Two Years	Nine Years	Two Years	Nine Years		
Malus baccata sanguinea (813) × Collins	1917		9	87	108	58	11	1	1									1	1	2	7	55	124	79	6	275	16.7	176.0	4.76	18.66	18.25	.216†
Rome Beauty × *M. atrosanguinea* (804)	1915	1	1	2	3	9	22	35	13	9	9	2								3	7	31	49	15	1	106	31.9	169.4	9.00	17.90	17.69	.181
M. prunifolia macrocarpa (837) × Jefferis	1917		3	15	26	36	13	10	1							1		1	3	5	8	34	40	12		104	20.6	160.2	6.37	26.67	26.74	.062
Rome Beauty × *M. floribunda* (821)	1914 1915		1	4	17	31	58	64	78	58	33	23	5	2				2	4	41	121	144	59	3		374	35.1	150.5	9.75	18.94	18.91	.077
Rome Beauty × Osimoe	1914		3	11	27	41	27	10	1										1	5	29	63	20		1	120	21.7	150.5	6 04	18 65	16.95	.188*
M. ringo (840) × Sweetbough	1917		4	29	36	38	31	16	4	3	2						1		5	14	47	62	32	2		163	21.7	147.1	8.02	21 90	21.46	.213†
Rome Beauty × *M. prunifolia* var. (838)‡	1912 1914, 1915		9	63	132	144	95	40	15	4							2	6	27	92	158	160	49	8		502	21.3	143 4	6.68	22.49	22.41	.097*
M. prunifolia var. (838) × Ben Davis	1912		4	17	46	27	11	2									2	1	1	11	37	40	14	1		107	18.4	143.3	5 18	21.80	21.31	.231*
M. prunifolia var. (838) × Collins	1915		4	18	53	43	54	19	9	2	1							1	7	31	64	69	30	1		203	22.8	142.8	7.25	20.76	20.78	.056
Rome Beauty × Yellow Siberian crab	1914	1	7	17	20	49	64	17	4							7	4	6	8	11	39	53	46	5		179	22.9	142 8	6 80	35 32	32.56	.394†
Duchess × Hall Number 6	1909	1	24	27	21	10	2										2	1	5	8	25	35	9			85	13.2	141 3	5.51	24.79	23.99	.272*
M. prunifolia var. (19651) × Sops of Wine	1917		1	8	33	41	30	26	15	2	3					2	2	5	10	23	41	55	16	5		159	25.1	138.6	7.86	29.26	28.64	.218†
Duchess × Fanny	1913		1	12	17	26	25	18	4	1								3	5	19	36	29	10	2		104	23.6	138.3	7.19	23.00	22.42	.243*
M. ringo (19662) × Longfield	1917		10	35	33	19	6	6	4	1							1	2	18	24	32	27	8	1	1	114	17.7	131.8	7.57	26.57	25.69	.271†
Duchess × Ben Davis	1913			8	21	31	32	9	4	3						1		1	8	34	31	28	4	1		108	23.7	131.5	6.70	22.87	22.34	.234*
M. baccata maxima (810) × Domine	1915		8	21	50	64	26	14	3							4	7	9	18	32	36	52	26	1		186	20.6	131 2	6.37	34.61	32.83	.324†
M. prunifolia var. (838) × Jefferis	1917	3	31	46	32	18	4	3							2	3	7	5	16	21	20	37	20	6		137	14.0	130.5	6.20	40.54	39.01	.284†
M. prunifolia var. (838) × Sops of Wine	1917	3	8	32	40	24	18	4	2		2					2	1	1	17	30	50	27	4	1		133	18.3	128.7	7.76	25.03	25.10	.044
Jonathan × *M. prunifolia* var. (838)	1915		6	11	27	26	28	19	4		1							3	15	39	42	20	3			122	22.7	126.2	7.71	21.41	21.46	.06 0
M. baccata (806) × Winter Rambo	1915	2	8	14	13	23	21	6	1							1	5	5	9	15	30	15	8			88	19.9	125.5	7 79	31.70	29.33	.392†
Jonathan × *M. atrosanguinea* (804)	1915		3	5	5	22	21	23	13	4	3					2	2	6	10	32	31	9	7			99	27.7	122.5	8.64	27.85	26.70	.300†
Wythe × Collins	1915	1	2	8	25	35	33	8	5								1	4	21	37	37	17				117	22.6	121.8	6.56	21.12	20.35	.283†

Longfield × *M. prunifolia* var. (856)	1916		5	19	43	31	15	1	1						1		8	4	18	26	44	11	3			115	18.7	118.4	5.58	29.01	29.14	.017
Duchess × Yellow Transparent	1909	5	46	19	3	1											1	7	12	24	23	7				74	8.6	118.0	3 60	21.84	21.70	.163
M. ringo sublobata (854) × Collins	1916	3	23	89	141	167	47	10	1	2						2	10	18	103	162	138	47	3			483	18.7	117 5	5.87	22.49	21.66	.273†
Duchess × Shackleford	1911	14	38	53	19	3											5	6	28	48	32	8				127	10.4	113.6	4.71	21.96	21.96	.088
M. scheideckeri (19646) × Isham	1915		1	5	15	30	27	8	12		1					3	8	10	20	18	27	9	4			99	24.8	111.9	7.22	33.64	33.64	.103
M. baccata (806) × Jonathan‡	1915	2	9	29	63	60	41	11								8	19	37	37	63	41	10				215	19.9	105 8	6.07	29.52	27.21	.393†
M. baccata (807) × Wealthy	1917	3	8	39	35	13	6	1	1						2	7	10	9	14	29	22	12	1			106	15.5	105.5	6.02	36.62	36.77	.044
M. malus (19667) × Sweetbough	1917	2	18	32	23	3									3	3	9	8	14	9	22	7	3			78	12.5	104 6	4.42	38.70	33.03	.530†
Wythe × Willowtwig	1913		5	10	27	34	18	10										13	43	41	7					104	20 9	103.3	6.32	15.35	15.26	.149
M. malus (19667) × Duchess	1915		3	11	16	29	23	13	7	3						3	9	19	23	26	19	6				105	23.7	101.9	7.93	29.88	29 56	.176
M. baccata var. *sieboldi* (814) × Duchess	1916	1	25	50	57	33	9	1							5	14	13	15	32	56	36	5				176	15.6	99.4	5.65	33.58	30.87	.400†
M. siberica frutico coccinea (19643) × Duchess	1916		16	71	69	29	8								3	27	10	24	50	61	15	2	1			193	15.5	91.4	4.83	31.97	28.83	.437†
M. baccata maxima (810) × Duchess	1916	2	74	183	254	119	37	5	1						39	62	50	133	203	147	37	4				675	16 1	89.4	5.31	31 31	28 74	.399†
M. ringo sublobata (854) × Ben Davis	1916		12	35	32	22	8	1								2	14	30	39	23	2					110	16.2	88.1	5 73	20.83	18.29	.486†
3188-3 (Rome Beauty × Grimes Golden) × Rome Beauty	1922 1926	3	30	40	23	10									2	7	18	24	42	13						106	12.1	85.5	4.78	22.51	21.96	.238*
M. baccata (806) × Grimes Golden	1914	1	9	37	58	41	15	1	1						11	16	29	24	24	35	17	7				163	17 6	85 2	5.63	36.58	32.96	.439†
Longfield × *M. baccata* (806)	1917	4	29	71	55	20	5								8	19	31	30	35	35	20	5	1			184	14.0	85.2	5.18	35 25	33.83	.290†
M. microcarpa (19644) × Osimoe	1916	2	50	106	103	37	3								14	33	35	81	81	48	10					302	14.2	83.1	4.72	28.55	25.99	.417†
3962-1-2 (Duchess × Ben Davis) × Ben Davis	1926	2	45	67	40	14	7									19	46	45	49	14	2					175	13.2	79.8	5.34	23.34	22.74	.238†
1911-A-4 (Wythe × Winter Rambo) × Winter Rambo	1926		8	67	71	24	8	1								16	40	69	48	5	1					179	15.6	79 2	4 57	19.48	19.15	.197†
M. baccata (807) × Jonathan	1916		11	54	126	74	17	1	1						18	59	51	83	60	13						284	17.5	69.5	4.71	26.10	25.00	.293†

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‡The cross and its reciprocal were grouped together since an inspection of their scatter diagrams as well as their statistical constants indicated that they were not markedly different from each other.

†Highly significant.

*Significant.

§The species names and numbers refer to the clons described by Crandall (2).

TABLE III—A SUMMARY OF THE PROGENIES SHOWING THE DISTRIBUTION OF THE SEEDLINGS IN EACH TWO YEAR CLASS AT THE NINE YEAR PERIOD

Classes for Height at the Two-Year Period (Inches)	Midpoints of Classes for Height at the Nine-Year Period (Inches)																							Total Number of Seedlings in Each Two-Year Height Class
	5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195	205	215	225	
0– 4	–	—	3	5	3	5	—	2	5	6	6	6	8	3	1	2	—	1	—	—	—	—	—	56
5– 9	2	11	31	39	34	32	42	36	45	48	58	39	52	46	48	21	10	7	9	2	—	—	—	612
10–14	–	6	29	51	67	67	90	95	140	142	159	134	127	122	96	81	69	39	36	21	6	1	—	1578
15–19	–	2	17	44	40	71	77	121	131	192	201	213	199	175	149	161	99	72	56	26	10	2	—	2058
20–24	–	—	5	9	21	28	25	60	65	106	139	164	171	180	167	159	129	94	43	25	15	2	2	1609
25–29	–	—	2	1	9	4	13	10	25	45	50	83	101	122	124	116	100	69	36	10	5	1	—	926
30–34	–	—	—	—	—	—	—	4	7	6	11	34	41	40	69	65	66	36	24	8	1	2	—	414
35–39	–	—	—	—	—	—	—	—	3	3	10	11	18	25	37	30	29	20	13	6	1	—	—	206
40–44	–	—	—	—	—	—	—	2	1	—	2	5	10	8	9	22	11	13	5	4	—	—	—	92
45–49	–	—	—	—	—	—	—	—	—	—	—	2	3	7	9	4	18	10	1	—	1	—	—	55
50–54	–	—	—	—	—	—	—	—	—	—	—	—	4	—	3	5	4	4	4	—	1	—	—	25
55–59	–	—	—	—	—	—	—	—	—	—	—	—	—	2	—	1	—	2	—	—	—	—	—	5
60–64	–	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	2
	2	19	87	149	174	207	247	330	422	548	636	691	734	730	713	667	535	367	227	102	40	8	3	7638

DISCUSSION

A straight line relationship was assumed in the calculation of all of the correlations according to the scheme outlined by Wallace and Snedecor (4). The fact that "r" is generally so low might be taken as support of the ever present possibility that the regressions were non-linear. However, all but 10 of the progenies definitely show a straight line relationship between the 2-year and 9-year measurements, and in only five of the progenies is there any considerable tendency toward a departure from linearity. In these cases even curvilinear regression leaves much to be desired in estimating the vigor of the trees at 9 years, so these progenies are also treated as though the regression were linear. Some implications of these curvilinear regressions are discussed further by Hough and Welker (3).

Since there is no basis for assuming that the genetic factors influencing growth would not have their proportionate effect at the 2-year period as well as at a later time, such as the ninth season, it will be of interest to present briefly some features which may have had a bearing upon growth to these seedlings as expressed in height. In the first place it will be recalled that the seedlings were planted three times — twice in the nursery and once in the orchard. As carefully as this work was done, it is conceivable that some seedlings would stand the necessary root cutting better than others or possibly recover more readily. The procedure followed seems necessary in this latitude, however, on account of rodent injury, "freezing out", winter killing and the difficulty of caring for small trees in the orchard. Secondly, seasonal differences in leaf injury from insects and diseases or differences in susceptibility or resistance, on the part of the seedlings could have a differential effect upon the efficiency of the leaves of individual trees, especially during the first years when the total leaf surface is small. Finally, soil differences in the nursery or orchard enter another unavoidable source of variation in the opportunity of the tree for growth. While the nursery area was given special cultural attention, it was not possible to eliminate the effect of either wet or dry periods. All told, therefore, it would be difficult if not impossible to handle material of this kind so that only the genetic factors would constitute the differentials in growth.

CONCLUSION

There would seem to be justifications, therefore, in concluding, on the basis of the analysis of the data presented, that the correlation between the height at the second year and the ninth year is not sufficiently close in apple seedlings handled in the way that has been described above to discard the smaller ones at the 2-year period. The high statistical significance of the 2-year–9-year correlations, coupled with the relatively low positive value of r may be looked upon as still further proof that, although there is a very real association, factors other than those that influence the 2-year height play a major role in determining height at the ninth year in the orchard.

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Comparison of Young Peach Trees on Shalil and Carolina "Natural" Rootstocks in Nematode Infested Soil[1]

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ATTACKS by the rootknot nematode constitute a serious drawback to peach growing in light sandy soils in the Southeast. It is probable that all fields that have been in cultivation for a long period of time are more or less infested. This has forced growers in the sandy soil areas to plant orchards on newly cleared land. Even then there is always the danger of infestation from neighboring fields by drainage water, tillage tools, or otherwise. Young peach trees are often killed outright in the first year or two in the orchard if severely attacked. Older trees may not be killed but are greatly weakened and made unprofitable. They are also more subject to other orchard ills.

Hutchins (1) reported in 1936 that the Shalil rootstock (F.P.I. 63850) had proved nematode-resistant in tests at Fort Valley, Georgia, and also that Hiley trees budded on this stock were markedly more vigorous than on "natural" seedlings. Certain commercial nurseries have propagated standard varieties on Shalil seedlings. The present experiment was initiated to study the performance of a standard variety commercially propagated on "natural" and Shalil seedlings in a nematode infested soil.

METHODS

An area of an old Elberta orchard planted on a deep phase of Norfolk coarse sand in 1928 was used for the test. About half of the original trees had died by 1940, with most of the losses attributed to winter injury or to the root-rot fungus *Armillaria mellea.* When the remaining trees were removed in the winter of 1940–41, it was found that practically every tree showed nematode galls on the roots. It was evident that the entire area was more or less infested with nematodes and also that the armillaria fungus was well distributed.

One-year-old 3- to 4-foot Halehaven trees budded on Shalil and on Carolina "natural" rootstocks were planted in alternate rows with 14 rows of 10 trees each on each rootstock utilizing the middles of the old Elberta tree rows. Several shovelfuls of top-soil were placed in the bottom of the hole when the tree was planted. After planting the trees and partly filling the holes, about 10 pounds of stable compost were placed around the trees, bringing the level to within 2 or 3 inches of the level of the ground. Other fertilization consisted of 1 pound per tree of a 4–8–4 fertilizer in 1941 and 2 pounds per tree of a 4–8–4 fertilizer and ½ pound of nitrate of soda in 1942.

The spring and early summer of 1941 were very dry. After heavy rains in July, there was another extended drought in late summer and fall. In 1942 there was abundant rainfall during the entire growing season.

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[1] Contribution No. 103 from the South Carolina Experiment Station.

GROWTH RECORD

When the trees were planted, it was obvious that the trees on "natural" rootstocks were much more uniform in size and shape than those on Shalil stocks. Furthermore, trees on the Shalil roots were somewhat dried out and showed other indications of poor handling in the nursery, while those on "natural" stocks were in excellent condition. All in all, the trees on "natural" stocks were by far the better lot and from all appearances should perform better in the orchard.

Both lots of trees made good growth in the spring and summer after planting, with those on "natural" stocks developing somewhat more uniformly. However, after the drought of August, many of the trees on "natural" stocks began to turn yellow and lose their older leaves. In contrast, the trees on Shalil roots remained green and in fine condition.

Although the trees on "natural" rootstocks were in very bad condition in the early fall, actual death of trees did not occur until the winter and following spring. Eighty-two of the 140 trees on "natural" stocks died during the first two years in the orchard, while only five of the trees on Shalil roots died. Of these, three of the former and one of the latter did not start into growth following planting. Examination of the trees when they were pruned in February showed that the dead trees had died from the branch tips back toward the trunk. Some trees were found with green wood in the trunk although all of the branches were completely dead.

The mortality record illustrates clearly the essential difference in the performance of the two rootstocks. However, growth records of the trees are also interesting. Diametric measurements of the trunks at a point 6 inches above the bud union were taken at the time the trees were planted and again at the end of the first and second growing seasons. For comparison, these measurements were converted into cross-section areas, assuming that the trunks were perfect circles. The trees on Shalil stocks were considerably larger at the time of planting than the trees on "natural" stocks with the mean cross-section areas being 1.42 and .96 square centimeters, respectively. The gain in cross-section area during the first season was also greater, being 2.25 square

TABLE I—COEFFICIENTS OF CORRELATION BETWEEN CERTAIN GROWTH CHARACTERS OF YOUNG HALEHAVEN PEACH TREES ON SHALIL AND CAROLINA "NATURAL" ROOTSTOCKS

Factors Correlated	Area of Cross-Section of Trunk at End of First Growing Season		Gain in Cross-Section Area During First Growing Season		Area of Cross-Section of Trunk at End of Second Growing Season		Gain in Cross-Section Area During Second Growing Season	
	Shalil Stock	Carolina Stock	Shalil Stock	Carolina Stock	Shalil Stock	Carolina Stock	Shalil Stock	Carolina Stock
Area of cross-section of trunk at time of planting	+.453	+.185	+.031	+.124	+.024	+.392	+.122	+.386
Area of cross-section of trunk after first year's growth	—	—	—	—	+.567	+.838	+.316	+.750
Gain in cross-section area during first season	—	—	—	—	—	—	+.388	+.734

centimeters for the trees on Shalil stocks as compared with 1.38 square centimeters for the trees on "natural" stocks. During the second season the gain was 17.41 square centimeters and 9.65 square centimeters, respectively. That the greater gain made by trees on Shalil roots cannot be logically attributed to their greater initial size is shown by the fact that the degree of correlation between size at time of planting and gain in cross-section area is very low (Table I). The second season gain of the trees on "natural" stocks was more highly correlated with initial size than was true in the case of the trees on Shalil roots. Similarly, correlations between first and second season's growth were higher in the case of trees on "natural" stocks. The reason for this is not clear.

That the trees on "natural" stocks were much more uniform in size when planted is shown by the variability coefficients given in Table II.

TABLE II—RELATIVE UNIFORMITY OF GROWTH OF YOUNG HALEHAVEN PEACH TREES ON SHALIL AND CAROLINA "NATURAL" ROOTSTOCKS AS INDICATED BY COEFFICIENTS OF VARIABILITY

Variable	Coefficients of Variability	
	Shalil Stocks	Carolina "Natural" Stocks
Area of cross-section of trunk:		
At time of planting	42.7	11.8
After first growing season	32.5	48.4
After second growing season	20.0	41.4
Gain in area of cross-section of trunk:		
During first growing season	47.0	81.5
During second growing season	22.5	45.3

However, it is also shown that gain in cross-section area was more uniform in the case of the trees on Shalil roots, and that at the end of the first and second years in the orchard the latter were more uniform in size than the trees on "natural" stocks. The variability in performance of the trees on "natural" stocks was probably due in large part to the difference in the severity of the nematode attack on individual trees.

NEMATODE INFESTATION

Nematode galls were found on the roots of all of the dead trees on "natural" rootstocks. The degree of infestation was quite variable, some trees having both large and small roots covered with galls, while other trees had only a few small galls on the fibrous roots. In August of the second growing season, all of the remaining living trees on the "natural" rootstocks and about 50 of the trees on Shalil roots were examined for nematode galls. Galls were found on roots of all of the trees on "natural" stocks thus examined; none were found on the trees on Shalil stocks. One of the trees on Shalil roots that died in 1941 did have nematode galls. Whether this was an instance of susceptibility of the Shalil stock or whether this tree was propagated on a stray seedling is not known.

Nematode galls were found on the "natural" seedling roots at a depth of 6 feet and were very evident at depths of 3 to 4 feet. It seems unlikely, therefore, that deeper root penetration as the trees become older is very effective in reducing the damage from nematode attacks in this soil.

DISCUSSION

The present test has demonstrated very strikingly a superior performance of Shalil rootstocks for peaches as compared with Carolina "natural" seedlings. It seems probable that the dry weather during the 1941 season aggravated the injury caused by attacks of nematodes. Many of the trees on "natural" rootstocks that died showed only slight evidence of nematode injury, which under normal moisture conditions would not have caused death of the tree. The death of these trees during the late winter and spring is strikingly similar to the death of trees usually attributed to winter injury. Observation of winter injury to peach trees in the sandhill area over a period of years suggests that such injury is closely correlated with soil moisture during the preceding summer and fall. It is very probable that nematode resistance in the peach would also mean a higher resistance to winter injury of the type that is usually experienced in light sandy soils. Whether or not the trees on Shalil roots were better able to withstand drought aside from their resistance to nematodes has not been investigated. Preliminary studies on the depth of the root system have not shown a significantly deeper penetration by the Shalil roots.

Evidence has recently been reported by Proebsting and Gilmore (2) that a chemical toxicity resulting from peach roots remaining in the soil of an old orchard site greatly affected the growth of young peach trees planted thereon. Although the present test afforded no direct comparison of trees on Shalil rootstocks planted on old and new orchard sites, it is quite evident from the vigorous growth of these trees that such toxicity, if present, did not prevent adequate tree development during the first two years. Many of these trees had attained a height of 7 to 8 feet and a limb spread of 8 to 10 feet by the end of the second growing season. The excellent performance of the trees on Shalil roots in this test should not be taken as a recommendation for replanting old orchard sites with trees on this rootstock. Resistance to other diseases such as armillaria root-rot and crown-gall that are apt to be present in old orchards has not been established for it or other peach rootstocks. Furthermore, it is possible that incompatibility between stock and scion may appear as the trees become older.

The present experiment has demonstrated a remarkable resistance to nematode injury by peach trees on Shalil rootstocks and has indicated that such trees will make normal growth on a nematode-infested old orchard site during the first two years.

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Variations in Root Knot Nematode Infection of Various Lines of Peach Progenies at Chico, California[1]

By J. C. Long and W. E. Whitehouse, *U. S. Department of Agriculture, Chico, Calif.*

INJURY to the roots produced by the root knot nematode, *Heterodera maroni* (Cornu) Goodey, is one of the limiting factors in commercial peach production in the lighter sandy soils in some of the southern portions of the United States. Workers (2, 3, 4, 5, 6, 7) have reported tests showing root knot nematode resistance of seedlings of certain varieties, those found resistant in this country coming for the most part from the collection of introduced peaches growing at the United States Plant Introduction Garden at Chico, California. Beyond experience derived from trials in limited areas (2, 3, 5), showing some quite promising, little is known as yet regarding the desirability of these few resistant rootstocks from the standpoint of growth, longevity and soil or regional adaptability; some lack vigor, others tend to sucker and one is sometimes winter injured in the nursery. Increase in the group of nematode-resistant forms available for selection will afford increased opportunity of developing rootstock lines combining desirable traits and diverse adaptabilities. As a result of the special emphasis which the Division of Plant Exploration and Introduction has placed, during the past decade, on introduction of peaches from all parts of the world, a large collection of material is available for such selection. This paper presents the results of the first two years' search for additional resistant lines at the United States Plant Introduction Garden, Chico, California.

MATERIALS AND METHODS

The parent material used represented both varieties and seedling peaches from various parts of the world. Initial choice of parent seedlings grown from introduced seed was made on the basis of tree, rather than fruit characteristics, but almost all were freestone. So far as possible open and self pollination progenies of each parent were tested. Self pollinations were effected by enclosing branches in cheesecloth sacks and brushing the flowers with a camel's hair brush at the proper time. In the 1941 test, each seedling progeny was replicated 10 times and in 1942 tests five times in randomized blocks, the seed planted 4 inches apart in the row and the rows spaced 4 feet apart. The tests were carried out on a light sandy soil in which infestation was obtained by planting pieces of nematode-infected potato tubers next to the seed; the checks (Lovell and Muir) indicate that infection was rather general. After the regular plots had been filled, excess seed of the replicated lots or seed available in lots too small for replication was

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[1] Grateful acknowledgment is made of the help rendered in this study by C. H. Jackson, who assisted the senior author and to Karl Gregoire, for many records taken after the departure of the senior author in 1942 to war emergency work.

planted in the spaces remaining in the blocks. Germination of seed, although variable, was high enough in the majority of cases to permit reliable reading. After one season's growth, the trees were cut with a nursery digger at a depth of 24 inches, lifted, the roots were washed and the infection was graded by macroscopic observation of the galls on the roots. Infection was classed at this time as heavy, moderate or light; the figures reported here are based on complete freedom or infection in any degree, however slight. Representative lots of trees showing no infection at the end of the first year were replanted for a second test. The source or varietal name of the female parent is given in the tables and all seedling selections whose progenies have shown outstanding resistance in these preliminary tests have been assigned Chico numbers and will be so designated in the future.

RESULTS

Results of the first seasons' test for the years 1941 and 1942 are presented in Table I; those from the second season of growth appear in Table II. Of the 47 peach progenies tested, other than Shalil, Yunnan (both already shown to be resistant) Lovell and Muir (both generally known to be susceptible) included for purposes of comparison, nine showed very high resistance to nematode attack during the first season of growth. All but one had less than 3 per cent infection on both the open and self pollinated seedlings and this exception (Chico No. 18) had only 6.5 per cent. These showings are comparable to those of the Shalil and Yunnan progenies grown in these tests. Of the nine that were highly resistant, two (Chico Nos. 11 and 12) came from China, the home of the nema-resistant Yunnan and Mao types; five (Chico Nos. 13 to 17 inclusive) from India, the home of the Shalil peach and Quetta nectarine and two (Chico Nos. 18 and 19) were introduced from Turkestan, Union of Soviet Socialist Republics, the home of the Bokhara peach.

The Tos China Settembre variety, which had approximately 20 per cent infection on the open pollinated and the selfed progenies during the first season of growth and less than 15 per cent on those which were grown a second season, is the offspring of a cross, made in Tuscany, between a hardy, late-ripening Chinese peach and the variety "Poppa diVenere" (1) and nematode resistance may have been transmitted by its Chinese parent. No outstanding resistance was found among the few peaches from Argentina that were testsd; reports of Worlock (7) and Carmon,[1] however, show progress in selection of resistant peach stocks in Argentina and Palestine.

Little or no difference in resistance was found between the open and the selfed seedlings in those progenies which were highly resistant to nematode but in those progenies which were only partly resistant, as for example those of the three seedlings of the peach from Shansi Province, China, the selfed seedlings were the more highly resistant in one case and the open pollinated in two. Progenies of one Shansi Province seedling (E–103–16) showed outstanding differences in favor of the selfed seedlings, particularly during the second season. In several cases considerably more resistance was found in the open pollinated seedling progeny. Weinberger, Marth and Scott (6) have reported the dominance of root knot resistance in the progenies of Shalil and the Yunnan peaches.

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[1] Carmon. Correspondence November 13, 1941.

Variability in resistance of open and selfed progenies from seedlings of similar parentage is illustrated in a comparison of Chico No. 19, which had practically no infection, with F–2–92 which ranged from 31.8 per cent in the selfed to 60 per cent in the open pollinated seedlings, the parents in both cases being seedlings from P. I. 105,056, a lot of seed received from Turkestan, Union of Soviet Socialist Republics. All progenies of the four different introductions of seed of Mao

TABLE I—Root Knot Nematode Infection on the Roots of Seedling Progeny of Introduced Peaches During the First Growing Season

P. I. Number	Station Designation	Source or Varietal Name of Parent	Test Year	Seedlings From			
				Open Pollinated Seed		Selfed Seed	
				Trees Tested (Number)	Per Cent Infected	Trees Tested (Number)	Per Cent Infected
			United States				
	N-2-7	Muir	1941	177	88.7	33	81.8
	N-2-5	Lovell	1941	125	88.0	112	89.3
	—	Lovell	1942	133	51.8	—	—
			China				
55885	E-14-15	Yunnan	1941	99	1.0	16	0.0
55885	E-14-15	Yunnan	1941*	50	0.0	—	—
55885	E-14-15	Yunnan	1942	74	2.7	70	0 0
55886	E-14-17	Yunnan	1941	239	0.4	91	0.0
55886	E-14-17	Yunnan	1941*	75	0.0	—	—
55888	E-14-19	Yunnan	1941	96	4.1	95	7.4
55888	E-14-19	Yunnan	1941*	117	2.5	—	—
	Chico No. 11	Shau Thai (65821)	1941	53	0.0	2	0.0
	Chico No. 12	Ngie (48694)	1942	74	0.0	72	0.0
	E-103-16	Shansi (95501)	1941	175	77.1	118	23.7
	E-103-12	Shansi (95501)	1942*	232	23.3	60	68.3
	E-103-15	Shansi (95501)	1942	94	37.2	132	71.2
	D-30-15	Chinese Turkestan (20503)	1942	258	45.7	213	53.5
	D-16-6	Fei (38469)	1942	117	79.5	59	84.8
	D-17-28	Eagle's Beak (43289)	1941	170	83.5	224	80.4
	D-17-28	Eagle's Beak (43289)	1941*	67	58.2	—	—
	D-28-29	Peking (71138)	1941	48	81.3	—	—
	E-2-11	Hsueh (72094)	1941	43	65.1	—	—
	D-8-24	Manchuria (92046)	1941	44	90.1	—	—
	D-30-35	Mao (65518)	1941	47	97.9	14	100.0
	F-1-99	Mao (101725)	1942*	8	75.0	25	56.0
	F-1-102	Mao (101725)	1942*	7	85.7	10	30.0
	F-3-114	Mao (106948)	1941	—	—	28	89.3
	F-3-114	Mao (106948)	1942	96	55.2	49	59.2
	F-3-115	Mao (106948)	1942	72	23.6	6	66.7
	F-4-98	Mao (107838)	1941	—	—	119	90.8
	F-4-98	Mao (107838)	1942	113	48.7	122	43.4
			India				
63850	E-4-22	Shalil	1941	29	0.0	71	2.8
63850	E-4-22	Shalil	1942	39	0.0	21	0.5
	Chico No. 13	Peshawar (103797)	1942	156	0.6	32	0.0
	Chico No. 14	Peshawar (103797)	1942	189	0.0	111	0.0
	Chico No. 15	Aru (116638)	1942*	63	0.0	43	0.0
	Chico No. 16	Aru (116638)	1942*	47	2.1	61	1.6
	Chico No. 17	Bannu District (127323)	1942*	15	0.0	35	0.0

TABLE I—*Concluded*

P. I. Number	Station Designation	Source or Varietal Name of Parent	Test Year	Seedlings From			
				Open Pollinated Seed		Selfed Seed	
				Trees Tested (Number)	Per Cent Infected	Trees Tested (Number)	Per Cent Infected
		Italy					
77870		Tos China Settembre	1941	95	20.0	259	19.3
		Union of Socialist Soviet Republics					
	Chico No. 18	S. E. Turkestan Mts. (105057)	1942*	185	6.5	—	—
	Chico No. 19	Turkestan (105056)	1942*	70	1.4	36	0.0
	F-2-92	Turkestan (105056)	1942*	30	60.0	107	31.8
	E-96-3	Andijan (82648)	1942	88	35.2	90	30.0
	E-96-1	Andijan (82648)	1942*	14	35.7	2	50.0
	E-96-5	Andijan (82648)	1942*	155	52.3	17	52.9
	D-10-7	Chimbai (84273)	1942	13	92.3	26	84.6
	F-4-18	N. Caucasus (104315)	1942	82	34.2	116	54.3
	F-3-120	N. Caucasus (104315)	1942	93	62.6	207	57.0
	F-3-128	N. Caucasus (104315)	1942	49	48.9	92	55.4
	F-2-129	Grudinskiy Celily (105059)	1942*	9	22.2	29	44.8
	F-3-21	Erivanskiy (105061)	1942*	8	87.5	8	62.5
	F-3-24	Erivanskiy (105061)	1942*	121	54.6	17	64.7
	F-3-90	Dagestanskiy Celily (105063)	1942	146	50.7	160	48.1
	F-3-89	Dagestanskiy Celily (105063)	1942*	188	38.3	—	—
	F-3-94	Yellow Zafrani (105064)	1942	95	29.5	126	69.8
	F-3-101	Rartule (105065)	1942	91	68.1	153	64.7
	F-3-106	Rartule (105065)	1942	195	58.5	88	42.1
	F-4-102	Ferganensis (109793)	1942	205	54.2	130	29.2
	F-4-103	Ferganensis (109793)	1942	265	54.7	264	43.9
		South America					
	F-4-52	Argentina (105466)	1942*	—	—	3	100.0
	F-4-105	Abobora (110267)	1942	165	66.3	174	48.9
	F-4-109	Amarella (110268)	1942	87	85.1	56	87.5
	F-4-110	Amarella (110268)	1942*	18	41.9	27	40.7

*Seedlings from extra spaces.

peach from China showed a relatively high range of nematode susceptibility during the first season's growth, though Weinberger, Marth and Scott (6) in reporting on tests with one of these introductions, P. I. 107838, found three of seven seedlings grown from seed to be free of root knot infection at the end of two and only moderately infected at the end of a 5-year test. Two of these three seedlings were grown to fruiting, the progeny of one being entirely free and that of the other 16 per cent infected when tested.

The second year's results confirm the first and indicate that the great majority, at least, of non-infected individuals in heavily infected lines owed their freedom to chance and were not truly resistant. On the other hand, the fact that the lines which were rather highly resistant in the first season showed little infection in the second suggests some degree of resistance. The difference between open and selfed progenies in the peach from Shansi Province appears as it did in the first year.

This test, conducted in one locality, and for a limited period, should not be interpreted as establishing definitely the value of the resistant

TABLE II—Root Knot Nematode Infection on the Roots of Seedling Progeny of Introduced Peaches During the Second Growing Season

P. I. Number	Station Designation	Source or Varietal Name of Parent	Test Year	Seedlings From			
				Open Pollinated Seed		Selfed Seed	
				Trees Tested (Number)	Per Cent Infected	Trees Tested (Number)	Per Cent Infected
		Lovell	1942	15	80.0	10	80.0
55886	E-14-17	Yunnan	1942	75	1.3	75	2.7
55886	E-14-17	Yunnan	1942*	74	2.7	13	0.0
55888	E-14-19	Yunnan	1942	75	1.3	75	6.7
55888	E-14-19	Yunnan	1942*	44	0.0	—	—
	Chico No. 11	Shau Thai (65821)	1942	50	0.0	—	—
	E-103-16	Shansi (95501)	1942	40	77.5	75	5.3
	E-103-16	Shansi (95501)	1942*	—	—	11	0.0
77876		Tos China Settembre	1942	75	14.7	75	12.0
77876		Tos China Settembre	1942*	—	—	120	8.3

*Seedlings from extra spaces.

strains as stocks for all varieties, locations and conditions. Its results, however, seem to point toward rather high percentages of nema resistance in peaches from certain areas, as Yunnan and the Northwest Province of India, and sporadic occurrence in other regions, as Turkestan and probably elsewhere. These results confirm the findings of other workers with reference to resistance in Shalil and Yunnan progenies, and to dominance of resistance in open pollinated progenies of these strains. In addition, however, they suggest that in cases in which resistance is diluted, the pollen parent may have some important influence. They show clearly, moreover, that individual seedlings from the same lot of imported seed do sometimes impart widely different degrees of resistance to their respective progenies and that comprehensive testing in this, as in other respects, is necessary to establish the character range of any seed introduction, even in self-fertile plants.

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Virus Diseases and the Stone Fruit Industry[1]

By E. M. HILDEBRAND, *Cornell University, Ithaca, N. Y.*

ABOUT a decade ago only five virus diseases of stone fruits were well recognized in the literature of North America. These were the well known peach diseases including yellows, rosette, little peach, red suture, and phony peach, of which the latter three are still of considerable economic importance. A recent publication (10) lists over fifty virus diseases affecting stone fruit plants in North America, including twenty-two on peach, fifteen on sweet cherry, seven on sour cherry, nine on plum, two on apricot, and one on almond. The above-mentioned publication includes a rather large number of diseases which are only partly worked out. Besides this list there are a considerable number of other abnormalities affecting commercial, ornamental, and wild Prunus species, many of which may also be of virus origin. Taken together they constitute the rather confused present-day situation which will take years to clarify.

The sudden impact on the stone-fruit industry of so many apparently new virus diseases has caused many to seek a plausible explanation for this sudden upsurge. While there has been much speculation as to the true cause for the present situation, proof is still lacking that viruses arise spontaneously.

The existence of strains within viruses, such as in cherry yellows, for example (9, 12), may be indicative of changes taking place and of mutability of these viruses; yet nothing is known of the nature of such changes. It is highly probable that most if not all of these "new" virus diseases have been in existence for a long time.

That certain viruses have undoubtedly been hidden away or masked in cultivated or wild plants is supported by recent researches. The finding of prune dwarf virus in apparently healthy Damson and Bradshaw plums (6) is one illustration. The presence of normal-appearing Damson and Bradshaw trees in Italian Prune orchards thus constitutes a hazard that must be recognized. While the Lombard plum is susceptible to the prune dwarf virus, it harbors in turn in a symptomless condition a latent virus (8) which induces a necrotic leafspot disease on the Italian Prune. The Shiro line-pattern virosis of Canada (1) was discovered when Shiro plum scions were grafted onto the Firsts plum, the symptomless carrier. Still other cases could be cited.

Other virus diseases affecting the stone fruits could have been imported in either fruit or ornamental plants. This is one possible explanation for the sudden appearance in this country of such diseases as peach mosaic and the yellow-red or X-disease of peach. An accurate appraisal of this contention is impossible because essential facts are lacking; besides there are also alternative explanations. For instance, in the case of the X-disease, which affects all peach varieties, the imported oriental flowering cherry, *Prunus japonica,* can be affected with the production of symptoms, whereas the wild American plum, *P. americana,* completely masks symptoms. There is the parallel case of this same plum masking "peach yellows" and "little peach" virus diseases. In the latter case it is generally agreed that the viruses are native ones since peaches are known to be affected only on this continent.

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[1] This paper was written to answer queries of horticulturists who were interested in a brief statement on the rôle of virus diseases in the stone fruit industry.

NONLETHAL VIRUSES

The fact that many of the cherry virus disorders have been ascribed to such causes as physiological upset, winter injury, spray injury, soil conditions and insects, makes these diseases of more than ordinary interest at the present time. One reason for not discovering their virus nature sooner could be that the affected trees were not killed, as is so often the case with the lethal peach viruses, namely, those causing rosette and yellows. The reduction in vitality and in fruitfulness caused by such diseases as cherry yellows and ringspot gives the outward aspect of winter injury, since weakened trees suffer more from the cold. Because such diseases are not lethal is no reason for considering them less important in the long run. Yield losses suffered year after year by cherry trees of up to 50 per cent or more from cherry yellows cannot be ignored. Although the percentage of affected trees in an orchard may be small at first, the disease continues to spread slowly. Some orchards with over 90 per cent of the trees affected are now under observation. It is important to remember that cherry trees affected with any of the several viruses do not recover in the sense of eliminating the virus. Instead they usually become worse with each succeeding year of infection. While it may not be feasible to eliminate affected trees, the production of healthy plants for starting new orchards presents a real challenge both to the pathologist and to the horticulturist. With the number of known virus diseases mounting steadily there would seem to be justification for an increased emphasis on these problems.

CURRENT ATTACKS ON THESE PROBLEMS

Some of the more important stone-fruit virus disease problems center around the following considerations: (a) Production of certified disease-free plants; (b) production of certified disease-free rootstocks; (c) improvement in experimental techniques; (d) discovery of the insect vectors; (e) discovery of better experimental plants; and (f) improved control practices.

Now for a brief consideration of the progress being made in the solution of these problems.

Production of Disease-Free Plants:—At the present time it is impossible to get certified disease-free plants for either experimental or orchard purposes. This is not surprising in view of the fact that methods for identifying and distinguishing many of the stone-fruit virus diseases have yet to be worked out. A committee (2) is at present engaged in formulating a minimum host range for use in comparative studies as an aid in the identification of these viruses. Perhaps the most that can be expected from such an effort is to give investigators a minimum basis for identification purposes which can be supplemented to fit local conditions. The development of disease-free foundation plants of different varieties will probably devolve upon the several States where the nursery stock is grown and should receive the combined attention of horticulturists and pathologists, because in any variety horticultural values are as important as freedom from disease. Besides, as indicated by experience with other viruses, such a problem cannot be solved once and for all. Rather, it will require the regular renewal of the selected stocks as necessity demands and this will involve the development of a more or less permanent program requiring cooperation between nurserymen, inspectors, and investigators.

Production of Disease-free Rootstocks:—Because the stone-fruit varieties are largely vegetatively propagated they are dependent on rootstocks about which practically nothing is known or has been done concerning virus affections. Consequently certified disease-free rootstocks are not available today. Failure to completely eliminate cherry yellows, for example, from nursery plants (7) by roguing out diseased plants and using disease-free budwood suggests that the rootstock as well as the scion may be the source of virus contamination in nursery plantings. A research program for the development of disease-free rootstocks which has been under way in New York State opens up problems of national scope because the sources of rootstocks are far removed from the fruit tree nurseries where they are used. To what extent the seed or seedling rootstock sources are implicated is for the future to determine. The extreme variability in growth-character and the appearance of mottlings and other abnormalities in the seedling rootstocks certainly are undesirable considered from any angle. The rather general occurrence of these abnormalities in many different sources of rootstocks is not suggestive of local origin and invites a cooperative study pooling the efforts of investigators in different parts of the country. It should be possible to certify seed-bearing trees for freedom from disease and to build up clean seed sources over a period of years without serious inconvenience either to nurserymen or fruit growers.

Improvement in Experimental Techniques:—That improved experimental techniques are needed for investigating the various virus diseases is indicated by the fact that the incubation periods of most of the woody-plant virus diseases may be long, some taking several years before symptoms show. Important progress has been made along this line by the employment of peach seedlings as test plants and the use of several techniques for stimulating the tree to new growth. One refinement is the use of peach varieties. The reason why symptoms fail to develop in actively growing peach trees inoculated with the yellow-red virus, for instance, appears to be that this virus cannot move up into the leaves against the downward flow of plant food. Evidently it is carried to the roots and is imprisoned there till the food stream goes upward again which occurs in sufficient amount only after the plant passes through dormancy, unless the plant food stream is reversed by severe pruning, defoliation or girdling (3, 4), or by shading (11). Such experimental techniques with the exception of shading, are ineffective unless the test plant responds promptly by producing new growth. Indexing cherry yellows on peach (5) employing a rapid transmission technique, shortened the incubation period, which is a year or longer on Montmorency cherry in the field, to about one month on seedling peach in the greenhouse. These rapid transmission techniques should also be applicable within limits to work in the field (3) based on limited studies with certain diseases.

Discovery of the Insect Vectors:—At present the insect vector is known for only two stone fruit virus diseases, peach yellows and little peach (13). This general lack of knowledge on natural means of virus transmission, which has been a stumbling block to progress, is not due to lack of interest on the part of investigators. It is more probably due to lack of knowledge and of skill in handling the potential vectors. Many sucking insects can be found on affected plants, some of which undoubtedly feed there, but the identification of the vector species from this complex has met with very little success to date.

Discovery of Better Experimental Plants:—Suitable experimental plants for studying the viruses affecting all the different kinds of stone fruit plants are not available at present. Peach seedlings and peach varieties on seedling roots are ideal test plants for studying not only the peach viruses but also a few of the plum and cherry viruses. Peach seedlings can be used to advantage both indoors and in the field because they can be started from seed at any season by cold-treating the pits. Comparable cherry and plum materials are not known. The Mahaleb (*Prunus mahaleb*) and Bessey (*P. besseyi*) cherries, while showing some promise, have much narrower host ranges, which reduces their usefulness. The same criticisms apply even more to Myrobalan plum and Mazzard cherry. Other plants like the chokecherry and Montmorency cherry which do not produce new growth quickly in response to such stimuli as pruning, defoliation, fertilization, and so on, are not suitable for greenhouse work where space and time are limited.

An important new development is the conduct of cooperative field experiments employing minimum host ranges including selected test varieties of peaches, plums, cherries, and their rootstocks in several different States[2] simultaneously comparing what are thought to be similar if not identical virus diseases.

Improved Control Practices:—There is a good deal of debate over the merits of quarantine regulations as they function in the control of virus diseases. That quarantines have a place is attested to by the fact that they are being used for combating certain diseases such as phony peach and peach mosaic. Yet their true merits are hard to evaluate because of the tendency for economic considerations to outweigh those of disease control.

Whereas the bases for removal of trees affected with such lethal diseases as peach yellows and peach rosette from nurseries and orchards are rather definite, those for the removal of trees affected with the slower-acting cherry viruses have not been settled because adequate evidence is not yet available on the extent of their detrimental effects on the productivity and longevity of the trees. To date, emphasis on control of cherry virus diseases has been placed on two things: (a) the gathering of data on the effects of the several viruses on the trees and on the commercial yields of fruit, and (b) the elimination of the viruses from nursery plantings to insure healthy trees for growers. These goals are far from being reached at the present time.

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[2] In 1942 the cooperating states were Michigan, New York, Wisconsin, and the Province of Ontario, Canada.

Considerable impetus has been given to this work throughout the country as a result of a meeting of stone fruit virus workers, horticulturists, and horticultural inspectors held in East Lansing, Michigan in September, 1941. One of the appointed committees has dealt specifically with the research aspects and it has prepared a report (2).

THE SITUATION AT PRESENT

From this discussion it can be concluded that the present status of the stone-fruit virus situation, while much improved over what it was several years ago, is still only in the beginning stages of solution. It is hoped that this commentary will enlist the cooperation of horticulturists to assist in clarifying objectives and thereby lead to greater progress in the solution of virus problems of the stone-fruit industry.

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An Attack of Fire-Blight Upon Trees of Pyrus Betulaefolia[1]

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PYRUS BETULAEFOLIA (Bge.) is a widely (3) distributed native of northern and central China. It is recommended as a potential rootstock material upon which to work the pear by abundant seed production, by vigor of seedlings, by freedom from leaf-blight (*Fabraea maculata* (Lev) Atk.) and woolly aphis (*Schizoneura lanigera* Hausmann), by production of specially vigorous nursery trees, and by adaptability to a wide range of climatic conditions.

In tests with pear rootstocks at the New York State Agricultural Experiment Station reported in 1933 (4) and 1934 (5), seedlings of *Pyrus betulaefolia* were notable for the large size of tree and good cropping when worked to the varieties Bartlett, Seckel, and Kieffer. In addition, the seedlings were outstanding from the nurseryman's point of view, in that for a 5-year period they were free from leaf-blight. This disease is severe in the nursery upon seedlings of the common or French pear (*Pyrus communis* L.), which are almost universally used as stocks for pears in America, and constitutes a serious fault. Further, the Oriental pears are as a class more resistant to fire-blight (*Erwinia amylovora* (Burr) Bergey et al) than *P. communis*, and it was hoped that *P. betulaefolia* might also prove resistant.

PROCEDURE AND RESULTS

Two types of *Pyrus betulaefolia* were selected for propagation and planting in the orchard as a future source of seed from which to produce seedling rootstocks. Type 1 was a single plant selection from a commercial lot of nursery seedlings of *P. betulaefolia* secured from Topeka, Kansas. Type 2 was from a tree of *P. betulaefolia* received from the U. S. Department of Agriculture as P.I. No. 45606 from seed from the Arnold Arboretum. The Arnold Arboretum specimens were originally from seed planted there in 1882, received from Dr. Breitschneider then living at Peking, China.

Both types were distinctly *Pyrus betulaefolia*, but varied in such minor characters as shape and pubescence of the young leaves. They were budded onto seedling rootstocks of *P. betulaefolia* and the resulting 2-year-old trees were planted in the orchard in 1938, five trees of type 1 and ten trees of type 2.

No leaf-blight was observed either on seedlings or on the orchard trees during three years in the nursery and six seasons in the orchard. They made vigorous growth. In 1942, a few branches were attacked by fire-blight, but the spread of the infection was not severe. However, in 1943, which was a severe blight year in New York State, all trees of this species were ravaged by fire-blight and either killed or so badly damaged as to make survival unlikely. The trees were in their sixth growing season in the orchard at the time, and were thrifty specimens. Flowers, twigs, spurs, and the larger branches and trunk of the tree were equally affected. Trees of McIntosh and Northern Spy apple were also severely affected by fire-blight at the same time to the extent of 40 to 50 blighted shoots on trees 4 years of age. Trees of Gorham and Seckel pear were affected less severely. In observations over a period of 23 years, the senior author has never seen fire-blight attack so sever and so completely devastating as on these trees of *P. betulaefolia.*

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[1] Journal Paper No. 567, New York State Agricultural Experiment Station.

Hansen (1) states that *Pyrus betulaefolia* received from several sources blights badly and that within a 20-year period all specimens have been killed by it in South Dakota. Hildebrand (2) says that in inoculation studies using a virulent strain of *Erwinia amylovora* all types of this species which he has tested have proved highly susceptible, in fact so susceptible that he has suggested its elimination from a program where blight resistance is concerned. Reimer (3) states that *Pyrus betulaefolia* is very nearly as susceptible to fire-blight in Oregon as *P. communis* in tips and trunks, but more resistant in roots than in tips and trunks. He lists it as more susceptible to fire-blight than any other oriental species except *P. phaeocarpa.* Nevertheless, he found 18 seedling trees of *P. betulaefolia* to be immune to fire-blight and perhaps of value. It is apparently to selected types such as these that horticulture must turn if *P. betulaefolia* is to be used as a blight-resistant material for the pear in the East.

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Some Instances of Scion Dominance in Citrus

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ALTHOUGH there is now a considerable body of literature on scion influence, the tendency to attribute all cases of dwarfing or invigoration to the effect of the rootstock still appears to be widespread. Indeed it seems generally to be assumed that the rootstock is the dominant member in the budded or grafted tree. The evidence is increasing, however, to support the view that the scion is fully as important as the rootstock and that frequently it is the dominant factor in determining whether the tree is to be dwarfed or invigorated. To place on record evidence which supports this conclusion with reference to citrus materials comprises the purpose of this report.

Materials and Methods

The materials here reported on consist of four lots of trees propagated in 1927 and planted in 1929 and 1930. Part of them have previously been described in other connections (1, 2, 3, 4). In all cases the rootstocks consisted of carefully selected seedlings of nucellar origin from single seed parent trees; the scions likewise were propagated from single mother trees. For each combination the trees were therefore identical as to both rootstock and scion clones.

The trees in the first lot consisted of Rough lemon (*Citrus jambhiri*) and trifoliate orange (*Poncirus trifoliata*) seedlings, part of which were self-budded, so as to contain bud-unions, and the remainder reciprocally budded. These two species comprise the most vigorous and least vigorous respectively of the rootstocks commonly employed for citrus trees in the United States. Reciprocal combinations of the two clones were thus available for comparison with trees of each clone containing a bud-union.

The trees were planted in pairs which were located within a short distance of each other. The members of each pair were remarkably alike throughout the period of the trial. At the end of the seventh growing season from planting the trees were measured and one member of each pair dug out as completely as possible. Photographic records were made and the dry weights of rootstock and scion determined for each tree. At the present time, 7 years later, the remaining members of each pair exhibit size relationships comparable to those which obtained at the time the other members were dug out.

The materials in the second lot consisted of five trees of one clone and six of another of the sweet orange (*Citrus sinensis*) and six trees each of the grapefruit (*C. paradisi*) and lemon (*C. limon*). The rootstock in all cases was sweet orange from one seed parent. The trees comprised part of a pruning experiment (2) in which three degrees of severity of treatment were compared. The trees of each clone were unusually uniform at the beginning of the experiment and the data obtained show almost equal uniformity in the treatments applied. Comparison between trees of the four clones given similar pruning treatment, all on the same rootstock, should therefore reflect scion influences. Half of the trees in each treatment were dug out in 1940, one year after treatment, the others a year later. Fresh weight determinations were made for both rootstock and scion, the latter consisting of the original weight of the prunings plus the remaining parts at the time of digging.

The third lot of materials consisted of sweet orange and lemon trees of two of the rootstock-scion clones included in the lot just described, also in a pruning experiment (3), but planted in another location. Here the pruned trees were given the same treatment except that both pruning and excavation were one year later in the case of the lemon trees. Further, it is to be noted that the control orange trees, though of the same age as the control lemon trees, were held in the nursery a year longer and hence planted in the orchard a year later.

The remaining materials consisted of a pair each of 10 gametic seedlings of the sour orange (*Citrus aurantium*) and one pair of a nucellar seedling of the same species, all of the same seed parentage and budded on nucellar seedlings of the sweet orange. As the standard with which to compare the budded trees, an unbudded nucellar sweet orange seedling of the same rootstock clone was used. The trees were planted 12 feet apart in a row. From the beginning, the gametic clones exhibited striking differences in foliar characteristics and vigor, all being less vigorous than the nucellar clone and some remarkably so. And from the outset the sweet orange rootstock seedling exhibited considerably more vigor than the nucellar sour orange clone on sweet orange rootstock. In all cases, however, the members of each pair of trees were remarkably similar throughout the duration of the trial.

At the end of the thirteenth year from planting, the trees were measured and photographed and one member of each pair of sour orange trees cut off at the bud-union. Shortage of labor rendered it impracticable to obtain the weights of top and root-system for all the trees so this was confined to the fresh weights for three of the gametic clones and the sweet orange rootstock seedling.

DATA AND RESULTS

Data and results from the first trial are shown in Table I and Fig. 1.

TABLE I—ROOTSTOCK-SCION RELATIONS IN RECIPROCAL COMBINATION (ALL WEIGHTS IN KILOGRAMS)

Tree Number	Scion-Rootstock Combination	Dry Weight of Scion	Dry Weight of Rootstock	Dry Weight of Tree
11 (6)	Trifoliate on trifoliate	9.08	4.10	13.18
9 (8)	Trifoliate on Rough lemon	20.62	5.15	25.77
9 (6)	Rough lemon on Rough lemon	70.26	17.29	87.55
11 (10)	Rough lemon on trifoliate	27.71	7.22	34.93

Comparison of trees 11(6) and 9(8) shows a pronounced invigorating influence of the Rough lemon rootstock, the trifoliate scion on that rootstock having a dry weight 2.27 times that of a similar scion on trifoliate rootstock. Likewise, comparison of trees 9(6) and 11(10) shows equally pronounced dwarfing effect of the trifoliate rootstock, the Rough lemon scion on that rootstock having a dry weight only 39.4 per cent that of a similar scion on the Rough lemon rootstock. Had the observations and measurements in this trial been restricted to the tops of the trees these results would undoubtedly have been attributed mainly or entirely to rootstock influence.

Further examination of the data and of Fig. 1, however, shows that scion influence has also played an important part in the growth of these trees.

Comparison of trees 11(6) and 11(10) (Fig. 1) shows a pronounced invigorating influence of the Rough lemon scion, the trifoliate rootstock under that scion having a dry weight 1.76 times that of a similar rootstock under trifoliate. Further, comparison of trees 9(6) and 9(8) (Fig. 1) shows an even more pronounced dwarfing influence of the trifoliate scion, the Rough lemon rootstock under that scion having a dry weight only 29.7 per cent that of a similar rootstock under Rough lemon.

While the data are much too scanty to warrant the drawing of general conclusions, the suggestion seems clear that the invigorating effect of Rough lemon as a rootstock is considerably greater (2.27 as

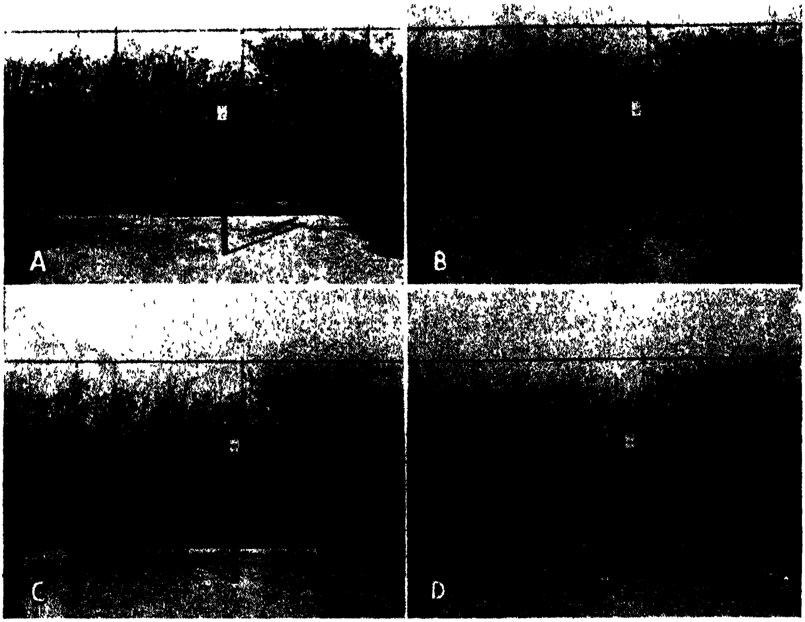

Fig. 1. Upper: Invigorating influence of Rough lemon scion on trifoliate orange rootstock. A—Trifoliate on trifoliate; B—Rough lemon on trifoliate. Lower: Dwarfing influence of trifoliate orange scion on Rough lemon rootstock. C—Rough lemon on Rough lemon; D—Trifoliate on Rough lemon.

compared to 1.76) than occurs when it is employed as the scion, but that conversely the dwarfing influence of trifoliate as a scion is more marked (29.7 per cent as compared to 39.4) than when it serves as the rootstock.

Some of the data obtained from the second lot of materials are given in Table II.

TABLE II—EFFECT OF GRAPEFRUIT, ORANGE AND LEMON SCIONS ON SWEET ORANGE ROOTSTOCK (ALL WEIGHTS IN KILOGRAMS)

Scion	Dug Out One Year After Pruning		Dug Out Two Years After Pruning	
	Fresh Weight of Scion	Fresh Weight of Rootstock	Fresh Weight of Scion	Fresh Weight of Rootstock
	Light Pruned			
Marsh grapefruit.........	193.36	54.04	192.19	51.50
Valencia orange..........	157.34	33.90	206.20	41.14
Washington navel orange	131.39	24.86	141.77	29.54
Eureka lemon...........	127.11	23.68	157.16	18.98
	Medium Pruned			
Marsh grapefruit.	138.17	32.28	165.53	43.00
Valencia orange..	172.96	39.75	176.30	41.10
Washington navel orange	125.30	27.45	——	——
Eureka lemon...	118.67	20.00	120.75	17.38
	Heavy Pruned			
Marsh grapefruit.........	164.60	32.26	176.02	41.86
Valencia orange..........	162.82	35.18	171.94	37.42
Washington navel orange	148.21	23.76	102.33*	22.08*
Eureka lemon...........	120.62	18.17	119.96	13.46

*Stunted tree.

That on the same rootstock the Marsh grapefruit and Valencia orange are considerably more vigorous than the Washington navel orange and Eureka lemon is clearly apparent. Moreover, both the total weights and the scion weights indicate that there is little difference in vigor between Marsh grapefruit and Valencia orange. If arranged in descending order with respect to total weight, both the largest and smallest halves of the lot of 12 trees consists of equal numbers of each clone. The average weight for the grapefruit trees is 216.13 kilograms; that for the Valencia orange trees is 212.67. And in the six comparisons of the two clones, in half the cases the grapefruit scion is larger than the Valencia scion, and vice versa. With reference to the comparative vigor of the Washington navel orange and Eureka lemon trees, the data indicate somewhat greater vigor for the navel orange. Thus of a total of five navel trees in the lot of 11, four occur in the largest half and the average weight is 155.34 kilograms as compared to 145.89 for the lemon trees. Moreover in three out of five cases the navel orange scion was larger than the lemon scion, in spite of the fact that one of the navel trees was obviously a "runt".

It seems clear therefore that the Marsh grapefruit and Valencia orange scions are approximately equal in vigor and considerably more vigorous than Washington navel orange and Eureka lemon, and that the latter is somewhat less vigorous than the former.

Turning now to the comparative weights of the sweet orange root-systems under these four scions, it will be noted that they exhibit almost exactly the same relationship as that borne by the four scions to each other. Thus the sweet orange rootstocks of the Valencia orange and grapefruit trees are without exception larger than those of the navel orange and Eureka lemon trees. In the comparison of grapefruit and Valencia orange, moreover, it will be seen that in four cases out of six the sweet orange rootstock was larger under grapefruit. However, in all cases this rootstock under navel orange was larger than under Eureka lemon, which suggests that the latter scion is definitely less vigorous, and hence more dwarfing, than the former. The conclusion seems inescapable that in these materials the scion has played the dominant role in determining both size of root-system and of tree.

Part of the data obtained from the third lot of materials are summarized in Tables III and IV.

TABLE III—EFFECT OF UNPRUNED VALENCIA ORANGE AND EUREKA LEMON SCIONS ON SWEET ORANGE ROOTSTOCK (ALL WEIGHTS IN KILOGRAMS)

Date of Excavation	Fresh Weight of Tree Minus Leaves	Fresh Weight of Scion Minus Leaves	Fresh Weight of Rootstock
	Valencia Orange		
Jan 18, 1940	146.55	104.05	42.50
Feb 10, 1940	156.30	106.84	49.46
Mar 1, 1940	168.64	122.38	46.26
Oct 4, 1940	186.28	132.98	53.30
	Eureka Lemon		
Mar 22, 1940	95.99	74.46	21.53
Apr 12, 1940	121.28	97.01	24.27
May 2, 1940	109.04	88.52	20.52
Sep 6, 1940	96.92	78.30	18.62

TABLE IV--EFFECT OF PRUNED VALENCIA ORANGE AND EUREKA LEMON SCIONS ON SWEET ORANGE ROOTSTOCK (TREES DUG OUT ONE YEAR AFTER PRUNING, ALL WEIGHTS IN KILOGRAMS)

Date of Excavation	Fresh Weight of Tree	Fresh Weight of Scion	Fresh Weight of Rootstock
	Valencia Orange		
Mar 15, 1940	213.06	175.26	37.80
May 17, 1940	170.92	140.16	30.76
Jul 19, 1940	192.65	163.71	28.94
Sep 20, 1940	211.89	175.35	36.54
Nov 15, 1940	221.52	184.54	36.98
	Eureka Lemon		
Mar 11, 1941	124.65	108.91	15.74
May 2, 1941	110.04	97.02	13.02
Jul 19, 1941	129.31	112.69	16.62
Sep 11, 1941	144.76	131.36	13.40
Nov 18, 1941	160.19	143.20	16.99

The same general relationships are shown by the data in these tables. Thus it is clear that on the same rootstock Valencia orange made a much larger tree than did the Eureka lemon. Likewise it is evident that the sweet orange root-system under Eureka lemon was much smaller than under Valencia orange.

While the trees reported on in Tables II, III, and IV are of the same age and the clones are genetically identical, the data are not directly comparable. The orange trees referred to in Table III were held in the nursery a year longer than the lemon trees, hence the comparison is favorable to the latter. And while the trees reported on in Table IV were planted at the same time, both the pruning and excavation of the lemon trees occurred a year later, a similar advantage in their favor. Moreover, the weights of tree and of scion given in Table III do not include the leaves whereas this fraction is included in the data shown in Tables II and IV. This was done in an effort to reduce the factor of variability, it having previously been shown that seasonal variability is greatest in this fractional part of the tree (4). And finally it should be mentioned that the trees reported on in Table III were completely excavated whereas those in Tables II and IV were dug out by a short cut method which excluded roots less than 0.8 of a centimeter in diameter. While these factors have unquestionably affected the actual values they have not materially influenced the ratios of the comparable sweet orange root-systems under the two scions common to all three lots of materials.

The data and results obtained from the last lot of materials are shown in Tables V and Fig. 2.

TABLE V—EFFECT OF SOUR ORANGE SCIONS ON SWEET ORANGE ROOTSTOCK

Scion	Trunk Circumference (Cms)	Top Volume (Cu Ft)	Fresh Weight of Tree (Kgms)	Fresh Weight of Scion (Kgms)	Fresh Weight of Rootstock (Kgms)
Nucellar	56.2	2805.0	—	—	—
No. 1	50.3	1644.0	253.16	224.46	30.70
No. 2	47.5	431.0	—	—	—
No. 3	41.0	646.0	—	—	—
No. 4	40.9	790.5	142.22	127.12	15.10
No. 5	38.3	509.0	—	—	—
No. 6	37.7	610.0	—	—	—
No. 7	36.8	516.5	—	—	—
No. 8	29.0	153.8	—	—	—
No. 9	28.1	129.0	—	—	—
No. 10	13.3	12.2	4.19	3.63	0.56
Sweet Orange Seedling	82.5	3790.0	582.27	460.40	121.87

The striking differences in size of sour orange scions, all on the same sweet orange rootstock, are obvious (see also Fig. 2) as is also the fact that the largest of these trees is considerably smaller than the sweet orange rootstock seedling. And that these differences are reflected in the corresponding root-systems is equally evident. Indeed it is apparent that the vigorous sweet orange rootstock has been pronouncedly dwarfed by all of the sour orange scions for which data were obtained and in direct proportion to the apparent vigor of the scion. That the scion has been the dominant factor in the size attained by these trees can hardly be doubted.

DISCUSSION

The data reported for the first lot of materials here discussed indicate that the rootstock-scion relation is reciprocal in nature and

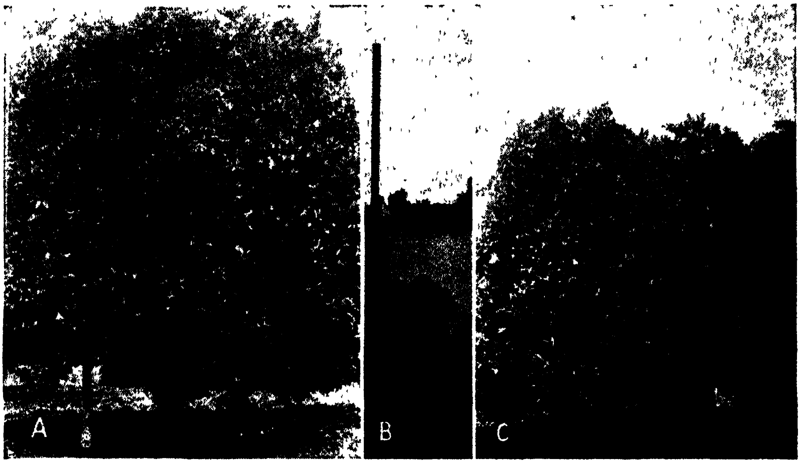

FIG. 2. Striking differences in vigor of sour orange scions on sweet orange rootstock, which were reflected in corresponding size of root-systems. A—Sweet orange rootstock; B—Sour orange No. 10 of Table V; C—Sour orange No. 1 of Table V. Trees all of the same age.

that the resultant tree is intermediate in vigor between its two component parts because of their simultaneous and opposing influences on each other. They suggest that the degree to which the rootstock and scion influence each other depends largely on the difference in vigor between them but that when the scion is less vigorous than the rootstock it tends to become the dominant factor. Thus the dry weight for the combination of trifoliate orange on Rough lemon was 25.77 kilograms as compared to 34.93 kilograms for the reciprocal combination. Barker (5) seems to have found a similar relation in young apple trees. It is to be noted, however, that he did not find the marked rootstock influence which is evident in our data.

The data presented for the second and third lots of materials show that on the same rootstock the Washington navel orange and Eureka lemon scions are materially less vigorous than the Marsh grapefruit and Valencia orange and that these differences are reflected in the corresponding root systems.

And finally, the data reported for the materials in the fourth lot show remarkable differences in the vigor of eleven sour orange clones all on the same rootstock, which differences likewise occurred in the corresponding root systems and in direct proportion to the apparent vigor of the scions concerned.

Since the one feature common to these combinations is the fact that the scion exhibits less vigor than the rootstock, the generalization seems reasonably safe that when this condition exists in young to medium-aged citrus trees the scion plays the dominant role in determining the size of the tree. Effects which appear to be predominantly of this nature have been reported and illustrated by Brown (6). As to whether this is also true when the scion is more vigorous than the rootstock remains to be determined. Evidence bearing on the importance of scion vigor in relation to the use of a semi-dwarfing rootstock has been reported, however (7).

SUMMARY AND CONCLUSION

Data obtained from 72 carefully propagated and selected citrus trees, consisting of combinations of 17 scion clones and 3 rootstock clones, of which the root-systems of 49 trees were excavated, have provided data which support the conclusion that in citrus trees the scion determines the rate of growth and ultimate size of tree when its vigor is less than that of the rootstock.

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An Uncongeniality of the McIntosh Apple When Top-Worked Onto Virginia Crab[1]

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THE Virginia Crab apple has been used successfully as a body stock for apples in sections where injury from winter cold is a problem and where the scion variety is subject to injury in the trunk and in the crotches (5). In Indiana, its use as a body stock has resulted in increased growth of Grimes trees (1) and increased yields of fruit over trees of the same variety not worked upon such a body stock (1, 3). Generally good results have been reported with many varieties employed (2, 5, 7).

Lantz, however, reported in 1933 (2) that Grimes and Starking made variable growth on Virginia Crab, some trees being normal and others being low in vigor. Maney reported in 1938 (7) that Virginia Crab gave somewhat peculiar reactions to different varieties. He found that with some members of the Winesap group it acted as a dwarfing stock. Stayman made a very weak growth on Virginia Crab, and the fruit was inferior in size, color, and quality. Mammoth Black Twig was decidedly dwarfed, but the foliage and twig growth were healthy and the fruit was normal. Paragon, which resembles Mammoth Black Twig so closely in fruit and tree characters that some have considered it synonymous with that variety, made a vigorous growth on the Virginia Crab stock, thus clearly identifying Paragon as a separate variety. Turley did well on Virginia Crab, while Winesap was perhaps half-dwarfed.

McClintock has reported (4) different degrees of affinity of several varieties top-worked on Virginia Crab. Rated according to vigor of growth and using the growth of Golden Delicious as 100, he found the performance of varieties as follows: Golden Delicious 100, Turley 97, McIntosh 94, Gallia 67, Starking 67, Grimes 65, Richared 56, Blackjon 50, and Blaxtamen 17. He considered the last named variety to be incompatible with Virginia Crab. Smith (9) has suggested that there are indications from his work in New Hampshire that some of the red strains of McIntosh apple are not completely compatible with Virginia Crab. Other reports, however, (4, 7) list McIntosh as entirely compatible with Virginia Crab.

Procedure and Results

Two-year-old nursery trees of Virginia Crab were secured from Iowa in the spring of 1938. There is no question but that they were the true Virginia Crab, being further identified in foliage and fruit in subsequent seasons (6).

Ten of these trees were top-worked during the dormant season in the nursery cellar (10) by heading back the three or four main scaffold branches to 8 inches and whip-grafting with 4-bud scions. Two trees each were top-worked in this way to Cortland, Kendall, McIntosh, Macoun, and Northern Spy. The scion wood was from young trees which had been propagated from bearing trees from the Station orchard.

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[1] Journal Paper No. 569, of New York State Agricultural Experiment Station.

The dormant top-worked trees were planted in the orchard in the spring of 1938. The grafts of Cortland, Kendall, and Macoun proceeded to develop strong shoot growth (4 to 5 feet) the first season, and the trees subsequently developed into vigorous orchard specimens characteristic of the varieties (Fig. 1, B, C, D). On the other hand, the grafts of Northern Spy and of McIntosh made only weak shoot growth (less than 12 inches), though the grafts apparently united with the Virginia Crab stock and remained alive during the first season.

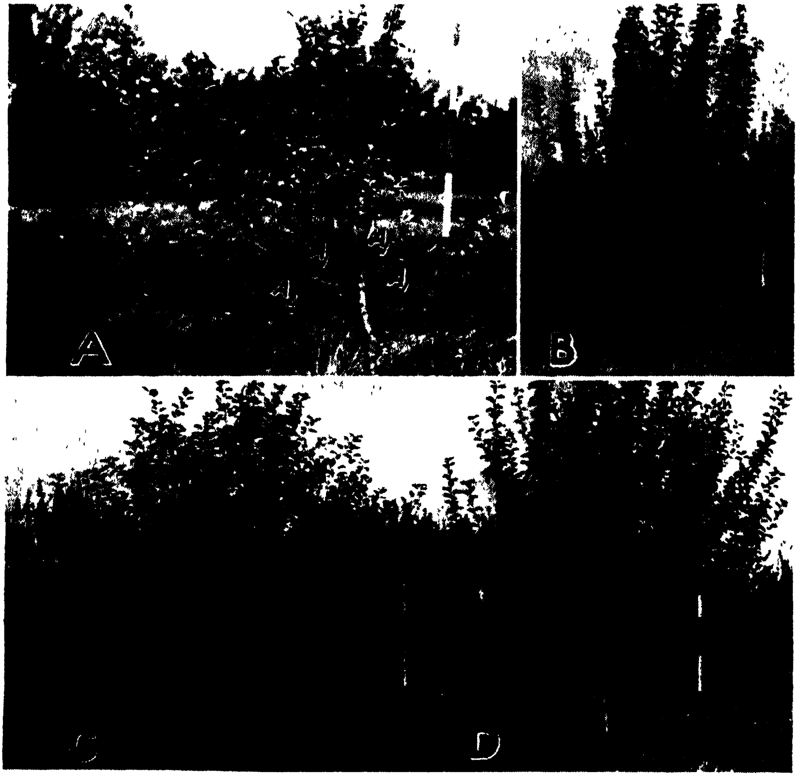

Fig. 1. Comparison of McIntosh, Kendall, Cortland, and Macoun when top-worked onto Virginia Crab (Six season's growth. Measuring stick divided into 12-inch sections). (A) McIntosh. (Because of poor growth of McIntosh scions at A_1, a scion of Baldwin was inserted at A_2 which grew vigorously as shown.) (B) Macoun. (C) Cortland. (D) Kendall.

During the summer of 1938, the trees which had been grafted with scions of McIntosh and Northern Spy, and which had failed to develop satisfactorily, were budded with six to eight buds of the same varieties. For comparison, buds of Cortland, Macoun, and Kendall were inserted into the trees which had been successfully top-worked by grafting with these varieties. In the ensuing growing season, the buds of Cortland, Kendall, and Macoun made vigorous growth (5 to 6 feet). On the other hand all of the buds of Northern Spy remained alive but dormant, and all died the second season. Similarly, 62 per cent of the buds of McIntosh remained alive and dormant but died the second season, and 38 per cent of the buds of McIntosh made weak growth (½ to 14 inches). Several shoots fruited the following season. One shoot has since developed a total growth of 4 feet during five growing seasons, but the branch is weak, of small diameter, has short internodes, and has born a few apples each year. The early fruiting and weak growth have been characteristic.

In the spring of 1939, while the trees were yet dormant, Baldwin grafts were placed on the trees on which the Northern Spy grafts had failed. The Baldwin grafts developed good shoot growth (5 to 6 feet), though the entire trees were checked by the severe pruning resulting from the unsuccessful top-working with Northern Spy.

Likewise, and at the same time, one of the trees on which the McIntosh grafts had failed, was whip-grafted on one side with McIntosh scions and on the other with Baldwin scions. The scions of McIntosh again failed to grow, although the scions of Baldwin grew vigorously (5 to 6 feet), forming a lop-sided tree with Baldwin growing on one side, which fruited heavily in 1943 (Fig. 1, A).

Again, in the spring of 1940, while the trees were still dormant, the second tree on which the scions of McIntosh had failed, were whip-grafted both to McIntosh and to Early McIntosh. The McIntosh buds united with the Virginia Crab stock but either failed or made weak growth (½ to 14 inches) (Fig. 2). The buds of Early McIntosh made fairly vigorous shoot growth (3 feet) but were not as vigorous as the buds of Cortland, Macoun, and Kendall previously described.

During the summer of 1941 the two trees on which McIntosh had

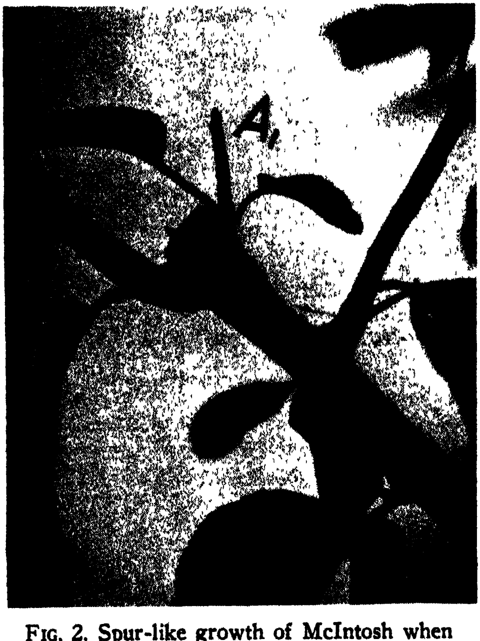

FIG. 2. Spur-like growth of McIntosh when budded onto Virginia Crab stock.

failed, were budded for the third time with buds of McIntosh. The buds again united, and in 1942 made weak growth of from ½ to 10 inches. By the summer of 1943 these spur-like growths had not elongated more than ¼ inch, although they were still alive.

Finally, during the summer of 1941, two unworked trees of Virginia Crab were budded with both Early McIntosh and McIntosh buds. The buds of Early McIntosh united and grew fairly vigorously (30 inches) during the season of 1942. Again, the buds of McIntosh made weak growth of 12 to 14 inches, the wood was of small diameter, the internodes were short, and the grafts bore one small apple during the season of 1943.

Discussion

Whether or not the type of McIntosh used in this work represents any special strain of that variety is not known. It is a slightly striped type which has been widely used in the Experiment Station orchards and in the western New York fruit area. Neither is it known whether or not the Northern Spy used in this work represents any special strain of that variety, though it, too, is a common type widely used in the Experiment Station orchard and in the western New York fruit area. It is of interest to note, however, that Shaw and Southwick (8) have reported a strain of McIntosh which is not compatible with U. S. D. A. 227, whereas a second strain is compatible.

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The Congeniality of Some American Varieties of Apples on Malling Rootstocks[1]

By H. B. TUKEY and K. D. BRASE, *New York State Agricultural Experiment Station, Geneva, N. Y.*

ONE of the problems in working with rootstock material for fruit trees is the question of compatability or incompatability of various stock and scion combinations. Interest in the Malling rootstocks, which are relatively new to orchard and nursery enterprise in New York State, makes it worthwhile to list the performance of varieties which have been tried on them to date. That is the purpose of this paper.

MATERIAL AND RESULTS

Sixteen types of Malling rootstocks were secured from the East Malling Research Station, England, in 1928 and propagated in stool-blocks on the Station grounds at Geneva, New York. On rootstocks from these beds, various varieties of apples have been tried at different times during an ensuing 14-year period. The trees have been propagated and have been planted and grown in the Station orchards. The propagation in the nursery was by budding; grafts make very poor growth in the western New York nursery area, so that propagation of fruit trees in the region is universally by budding. The budwood was either directly from bearing trees in the Station orchard or from young trees propagated from bearing trees.

In the accompanying table (Table I) are listed 210 combinations which have been tried with the Malling rootstocks over a period of 14 years, mostly varieties of American origin but including a few of foreign origin grown in America. They represent all of the combinations which have been tried, without regard to possible success or failure. Some of the combinations have been tried in the nursery for one season; others have been tried as many as 10 different seasons (column 2). The age which the trees have attained at the time of this report, 1943, varies from 14 years to only 1 year in some instances (column 3). It should be made clear that the age of tree has nothing to do with longevity, but merely indicates the age which the tree has attained at the time of this report.

DISCUSSION

It is noteworthy that of all the combinations tried, totaling 210, during 14 different seasons, representing 40 different varieties and 14 different rootstocks, not a single one has as yet been found which is incompatible in the nursery. Neither have any combinations proved incompatible in the orchard, though it is too early in some instances to say that incompatibilities may not show up in time.

The general impression from the data is one of high degree of compatibility of a relatively wide range of varieties on the Malling rootstocks. This is in contrast to the incompatibilities with U. S. D. A. 227

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[1] Journal Paper No. 568, New York State Agricultural Experiment Station.

TABLE I—VARIETIES OF APPLES WHICH HAVE BEEN TRIED UPON THE DIFFERENT MALLING ROOTSTOCKS, TOGETHER WITH THE NUMBER OF SEASONS IN WHICH THEY WERE TRIED, AND THE AGE OF THE OLDEST SCION IN 1943**

Variety	Number of Seasons Propagated	Present Age of Orchard Trees (Years)	Variety	Number of Seasons Propagated	Present Age of Orchard Trees (Years)
		Malling I			
Baldwin	9	14	Milton	1	7
Cortland	4	10	Northern Spy	5	13
Delicious	10	13	Rome	2	4
Early McIntosh	1	13	Red Spy	1	8
Fameuse	1	8	Roxbury	1	7
Gallia Beauty	4	8	Stark	1	8
Golden Delicious	4	4	Starking	1	4
Grimes	1	8	Staymared	1	4
Jonathan	1	*	Tioga	1	*
Kendall	4	10	Turley	2	8
Lodi	1	*	Wealthy	4	4
Macoun	4	11	Winesap	1	4
McIntosh	10	14	Yellow Newtown	1	8
		Malling II			
Baldwin	3	13	Gravenstein	1	*
Cortland	4	4	Macoun	1	4
Cox Orange	2	3	McIntosh	6	13
Delicious	4	13	Northern Spy	4	13
Early McIntosh	1	13	Rome	1	3
Golden Delicious	3	*	Turley	1	*
		Malling III			
Baldwin	3	13	Macoun	1	*
Cortland	5	5	McIntosh	7	5
Cox Orange	2	*	Northern Spy	4	13
Delicious	6	12	R. I. Greening	2	5
Early McIntosh	3	13	Rome	2	*
Golden Delicious	1	*	Turley	1	*
Grimes	1	*			
		Malling IV			
Baldwin	3	13	Macoun	1	4
Cortland	4	5	McIntosh	7	13
Cox Orange	1	3	Northern Spy	5	13
Delicious	6	13	R. I. Greening	2	5
Early McIntosh	1	13	Rome	2	*
Golden Delicious	1	*	Turley	1	*
Kendall	2	4			
		Malling V			
Baldwin	3	13	Golden Delicious	1	*
Cortland	4	*	Macoun	1	*
Cox Orange	1	*	McIntosh	6	13
Delicious	4	13	Northern Spy	2	13
Early McIntosh	1	13	Rome	1	*
		Malling VI			
Baldwin	3	13	Golden Delicious	1	*
Cortland	1	*	McIntosh	5	10
Delicious	3	13	Northern Spy	1	9
Early McIntosh	1	13			
		Malling VII			
Baldwin	4	13	Kendall	2	4
Cortland	5	5	Lodi	1	4
Delicious	5	13	Macoun	2	3
Early McIntosh	2	13	McIntosh	7	13
Gallia Beauty	1	*	Northern Spy	4	13
Golden Delicious	1	4	Red Astrachan	2	5
Gravenstein	2	5	R. I. Greening	1	*
Grimes	1	*	Turley	1	1
Jonathan	1	3			

*Combinations which were grown for 2 years in the nursery but which for lack of room were not planted in the orchard.

**All combinations have so far proved compatible.

TABLE I (*concluded*)

Variety	Number of Seasons Propagated	Present Age of Orchard Trees (Years)	Variety	Number of Seasons Propagated	Present Age of Orchard Trees (Years)
		Malling VIII			
Baldwin	1	1	McIntosh	2	2
Cortland	1	1	Northern Spy	2	2
Delicious	1	1	R. I. Greening	1	1
Early McIntosh	1	1	Wealthy	1	1
Grimes	1	1	Webster	1	1
Jonathan	1	1			
		Malling IX			
Baldwin	8	13	Oldenburg	2	*
Cortland	5	5	Rome	1	*
Cox Orange	3	8	Red Astrachan	1	5
Delicious	7	13	Red Gravenstein	1	*
Early McIntosh	3	13	Red Spy	1	8
Fameuse	1	*	Roxbury	3	7
Gallia Beauty	2	8	Stark	1	8
Golden Delicious	1	6	Tioga	1	*
Grimes	2	8	Tompkins King	1	8
Gravenstein	1	5	Turley	3	8
Jonathan	2	8	Wagener	1	8
Kendall	2	3	Wealthy	1	*
Lodi	1	*	Webster	2	*
Macoun	4	10	Winesap	1	8
McIntosh	6	13	Wolf River	1	8
Milton	2	7	Yellow Transparent	1	*
Northern Spy	6	13			
		Malling X			
Baldwin	1	9	Jonathan	1	*
Delicious	1	13	McIntosh	1	*
Early McIntosh	1	13	Northern Spy	1	13
Grimes	1	*	Rome	1	*
		Malling XII			
Baldwin	5	13	Macoun	1	*
Cortland	5	5	McIntosh	8	14
Delicious	7	5	Medina	1	*
Early McIntosh	2	*	Melba	1	4
Gallia Beauty	4	5	Northern Spy	3	13
Golden Delicious	1	*	R. I. Greening	5	6
Grimes	1	8	Rome	1	*
Jonathan	1	8	Tioga	1	*
Kendall	2	5	Turley	2	4
Lodi	2	*	Wealthy	4	*
		Malling XIII			
Baldwin	7	13	Medina	1	*
Cortland	6	10	Melba	1	5
Delicious	9	10	Milton	1	5
Early McIntosh	2	13	Northern Spy	3	13
Fameuse	1	*	Oldenburg	1	5
Gallia Beauty	4	8	R. I. Greening	5	8
Golden Delicious	1	5	Rome	5	5
Gravenstein	1	*	Tioga	1	*
Kendall	4	10	Turley	3	5
Lodi	2	*	Twenty Ounce	1	6
Macoun	3	10	Wealthy	5	4
McIntosh	10	14	Yellow Newtown	1	8
		Malling XVI			
Baldwin	3	13	McIntosh	6	13
Cortland	4	5	Northern Spy	2	13
Delicious	5	13	Tioga	1	*
Early McIntosh	1	13	Wealthy	2	4
Gallia Beauty	3	4	Yellow Transparent	1	*
Kendall	2	6			
		Malling XVII			
Baldwin	1	13	McIntosh	1	*
Delicious	1	*	Northern Spy	1	*
Early McIntosh	1	9			

*Combinations which were grown for 2 years in the nursery but which for lack of room were not planted in the orchard.

(1, 2) and Virginia Crab (3), both of which have been in use only a short period of time. One wonders whether in the course of time with the older rootstocks, such as most of the Malling rootstocks, uncongenial types may not have been naturally eliminated, whereas uncongenialities among new rootstocks are more in evidence because they have not as yet undergone this selective process. The possibility also exists of a closer botanical relationship between the cultivated American varieties and the Malling rootstocks than Virginia Crab and U. S. D. A. 227.

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The Influence of the Rootstock on Seeds and on Seedling Progenies of Tomato Grafts

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THE reciprocal influences of stock and scion have long been observed. Reports of such influences have been confined, however, almost entirely to the somatic tissues involved in the graft, that is, with the effect of the stock on the scion and its parts, including flowers and fruits, and with the effect of the scion on the stock and its parts. The material contained in this paper records the possible effect of the rootstock on the seed produced by the scion and on the behavior of seedlings grown from such seed.

Only one instance of similar nature has come to the author's attention, and it will be reviewed but briefly. Hoffman (1) after grafting scions of *Phaseolus vulgaris* L. on *P. lunatus* L. stocks and vice versa observed that, aside from certain direct and reciprocal effects of stock and scion, seedlings derived from both kinds of grafted plants could be cross-inoculated successfully with either specific group of nitrogen fixing bacteria characteristic respectively for the two species of bean.

MATERIALS AND METHODS

The scion variety used was the Earliana tomato. The plants on which they were grafted were of the following species: *Datura stramonium* L. (Jimson weed), *Nicotiana tabacum* L. (common tobacco), *Solanum tuberosum* L. (Irish potato), *S. nigrum* L., var. guineense (Wonderberry), and *Lycopersicon esculentum* Mill. (tomato). These stock species cover quite a wide range in vigor expressed in terms of size. Stock plants were started early enough to insure material of sufficient size for top working with tomato. When these had become of suitable size and succulence, tomato seeds were sown in sand flats to provide uniform scion material. After the tomato seeds had germinated and the seedlings were acquiring their first true leaves they were removed from the sand and washed in clear water.

The stock plants were cut down to low stumps, between 4 and 8 inches in height. At suitable places and depending on the size of the stems, two or more radial cuts were made to receive whole-rooted seedlings as scions. As far as the author knows, the use of entire plants for scions in this way in cleft grafting has never been recorded. The roots of the tomato seedlings were securely wedged up to their crowns in the radial stem slits and then firmly bound with No. 18 white cord. After union of stock and seedling scions was effected, all grafts but one were removed so as to establish the desired type of single-top plants. Thereafter, all plants were treated uniformly according to their water requirements and staked according to needs. When flowers appeared, they were self-pollinated. Seeds from some of the resulting fruits were saved for germination. Later seeds were sown in alternating rows in a standard flat of prepared soil. Three successive sowings were made at repeated intervals in order to confirm observations made on the order of seed germination and on seedling vigor.

RESULTS AND DISCUSSION

Aside from certain definite differences observed on scion vigor and fruitfulness the following results are of special interest. Of the four seed lots taken from tomato fruits, those grown on *Datura stramonium* stocks were the earliest to emerge from the soil, and the resulting seedlings were observed to be the most robust; those grown on *Nicotiana tabacum* stocks were last to emerge, and the seedlings were the smallest in size and vigor; those grown on *Solanum tuberosum* and on *Lycopersicon esculentum* stocks were about midway in time of emergence from the soil, and the seedlings were about midway in size and vigor. No fruits ripened on the Wonderberry stock.

CONCLUSION

When seeds were taken from self-pollinated flowers of grafted plants, observations on time of seed germination and on size and vigor of the resulting seedlings indicate that an influence may emanate from the rootstock that may not only affect the scion directly but also may affect the seeds produced by the scion and the performance of the resulting seedlings, that is, the members of the succeeding generation.

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Characteristics in the Nursery of Tung Progenies from Open-Pollinated Seed of One Hundred Sixty-Nine Parent Trees

By SAMUEL MERRILL, JR., *U. S. Department of Agriculture, Bogalusa, La.*

IN establishing the commercial tung orchards of the United States, which are comprised wholly of seedling trees, the best growers have practiced mass selection. Until recently, few instances were known in which trees could be traced to the seed of one individual parent tree. From 10 trees planted on the grounds of the Florida Experiment Station in 1912 to 1914, seed was harvested and distributed widely in the early days of the tung industry. In 1930 seed of two of these trees, numbers 2 and 9, was planted separately in an orchard on the grounds of the Florida station, and Dickey (3) has described the characteristics of the two resulting seedling progenies.

In 1937 Gaston Lanaux, of Folsom, Louisiana, obtained seed from a tree in that locality, known as the McKee tree. He mixed this with some seed from trees known to have come from selfed[1] seed of the original McKee tree and obtained a 30-acre orchard that, for its age, is now outstanding for productivity and tree uniformity.

The United States Field Laboratories for Tung Investigations began making selections of tung trees for propagation and breeding purposes during the fall of 1938. In 1939 and 1940, more than 500 lots of seed, each from an individual selected parent tree, were planted in the nursery. The resulting seedling trees were studied in the nursery and transplanted to commercial orchards where their characteristics can be determined up to and including bearing age. Important information as to the value of different individual trees as seed parents may thus be gained. The data obtained have already been used as a criterion for selecting seed sources for root stocks. In addition the data give a valuable insight into the fundamental genetic constitution of the species *Aleurites fordii.* The purpose of this paper is to present data on the growth and branching habits of the seedlings during their first season, when they were in the nursery.

EXPERIMENTAL PROCEDURE

In 1939 the Experimental Tung Farm near White Sand, Pearl River County, Mississippi, where this work was conducted, was just being cleared and time did not permit planting the different progenies[2] of seed in replicated randomized plantings that would yield data for reliable comparisons between progenies. In 1940, 169 lots of open-pollinated seed from selected parent trees were planted in a new nursery in an experiment laid out according to the lattice design. This design is well suited to the testing of large numbers of varieties, especially when little is known about the variability of the experimental field. The rather large replications are broken down into small "incomplete blocks" and the technique permits adjustment of variety means for block effects caused largely by soil differences.

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[1] It is believed that no cross pollination took place because at the time there was no other tung tree within a radius of about 4 miles.

[2] In this paper any lot of seedlings grown from the open-pollinated seed of a single tree is designated a "progeny".

The soil on which these seedlings were grown was below average in fertility. The growing season was characterized by a 5-week drought in May, shortly after germination of the seed. Some drought at this period of the year is not uncommon in the tung belt of the southern United States, though in southern Mississippi it is usually not so prolonged. The trees made only fair growth, averaging 76 centimeters in height at the end of the growing season. The potentialities of the 169 progenies would no doubt have been more fully developed, and the differences between the strains would have been accentuated, had the plants been under more favorable growing conditions. Not a single one of the 169 progenies developed branches on every tree. Yet extended observations in tung nurseries indicate that had growing conditions been favorable, one would expect several progenies to have attained practically 100 per cent branching. However, no further opportunity offered itself to plant and compare a large number of different progenies. Therefore, the data from this experiment are presented herewith.

Data were taken on (a) germination, (b) height, (c) diameter, and (d) the number of branched trees, and were analyzed by the method of Cox, Eckhardt, and Cochran (2). The plot consisted of a planting of 35 seed at approximately 1-foot intervals in a single row. Four replications of the 169 progenies were used. Thus there was a total of 676 plots of 35 seed each, which formed the basis for the data on germination. As the number of plants in the plots was variable, the first 10 trees in each plot were measured for data on tree characteristics. The data on branching were computed as percentages. Bliss (1) has pointed out that certain percentage data are not suitable for statistical analysis unless "transformed" to angles. Bliss's procedure was followed and estimates of the significance of percentages or differences in percentages were made by statistical analysis of the transformed data.

RESULTS

Limitations of space preclude publication of all the data. Table I presents essential data from four analyses of variance. The values of *F* show that the variations between progenies in the four characteristics studied were highly significant. Further, according to Cox, Eckhardt, and Cochran (2), if analysis as randomized complete blocks indicates that significant differences exist between varieties, one is justified in proceeding to calculate progeny means adjusted for positional effects and studying differences between these adjusted means by standard errors based on the inter-block mean squares for error. The inter-block error mean square shown in Table I is smaller than that calculated on the basis of randomized blocks, because more of the error due to soil variability is eliminated. Accordingly the adjusted means have been calculated and in Table II some of the outstanding values for germination, height, diameter, and percentage of branched trees are shown.

TABLE I—MEAN SQUARES AND VALUES OF *F* FOR FOUR GROWTH CHARACTERISTICS OF ONE HUNDRED SIXTY-NINE PROGENIES

Growth Characteristic	Unit of Measure	Analyzed on Basis of Randomized Blocks			Analyzed on Basis of Lattice Design Error (Mean Square)§
		Error (Mean Square)*	Progenies		
			Mean Square†	*F*‡	
Germination (plants emerged)	Number	10.37	89.85	8.66	9.93
Height of tree......	Centimeters	245.39	389.89	1.59	166.14
Diameter of trunk..	Centimeters	0.0598	0.0956	1.60	0.0416
Proportion of branched trees	Percentage (transformed to angles for statistical analysis)	148.42	635.74	4.28	137.01

*504 degrees of freedom. This mean square used to compute *F*
†168 degrees of freedom.
‡*F* at .01 point = 1.42.
§456 degrees of freedom.

As a matter of local interest, the data have been arranged according to the states in which the parent trees were selected.

The greatest mean germination, 32.4 out of 35 seeds, was attained by a Mississippi selection, M–43. An examination of all possible differences in germination among the 169 progenies shows that 3342 of these had statistical significance at the .001 level. Among 169 progeny means

$$\frac{169 \times 168}{2}$$

or 14,196 independent comparisons can be made. Hence on chance alone, it is to be anticipated that about 14 differences would exceed 7.44, the least difference significant at .001 under the conditions of the experiment. It is clear that the progenies are inherently diverse in germination.

The greatest mean height, 111.5 centimeters, was attained by a Mississippi selection, M–39. The differences in height between this progeny and 116 of the shortest progenies were highly significant (.001 level). Similar comparisons for height were made between other progenies. These tests reveal that the 14 tallest progenies were each significantly taller than one or more other progenies in the experiment when tested at the .001 level. The total number of differences in mean height significant at this level was 257. In the same manner, 13 progenies were outstanding for large diameter and, as indicated by the data in Table II, 235 differences in mean diameter were significant at the .001 level. Likewise, there were 24 progenies outstanding for high percentages of branched trees and 1691 differences in percentage branching that were significant at the .001 level.

The numbers of highly significant differences found were so much greater than the number expected on the basis of chance that one must conclude that the 169 selected tung trees produced characteristic progenies that differed inherently in germination of seed, height of tree, diameter of trunk, and percentage of trees branched.

One might expect that some of the parent trees would be more heterozygous than others, and hence that the several progenies would differ not only in mean values of measurable characters but also in

TABLE II—RANGE OF MEAN VALUES OF CHARACTERISTICS OF TUNG PROGENIES FROM OPEN-POLLINATED SEED OF ONE HUNDRED SIXTY-NINE PARENT TREES (WHITE SAND, MISSISSIPPI — 1940)

Location of Parent Tree	Progenies in Experiment (No)	Germination (No)*		Height (Cms)		Diameter (Cms)		Trees Branched (Per Cent)†	
		Lowest Progeny	Highest Progeny	Lowest Progeny	Highest Progeny	Lowest Progeny	Highest Progeny	Lowest Progeny	Highest Progeny
Florida. . . .	118	2.2	31.2	56.0	97.1	1.09	1.87	0.0	45.0
Georgia . . .	15	11.7	30.6	57.0	100.8	1.14	1.80	0.0	20.0
Louisiana. . . .	24	14.5	31.1	58.2	93.2	1.13	1.62	0.0	72.5
Mississippi. . .	12	13.4	32.4	72.6	111.5	1.26	1.86	0.0	30.0
Least difference significant at .001 level		7.44 seeds germinated		31.6 centimeters		0.50 centimeter		—	
Total number of differences that equal or exceed least difference significant at .001 level.		3342		257		235		1691‡	

*Out of 35 seeds planted.
†Actual percentages, not adjusted for block effects.
‡These differences calculated from analysis of angular transformations of percentages.

uniformity. The variance of each of 165 progenies, with place effect largely eliminated, was calculated for height and for diameter of the trunk. It will be remembered that individual measurements of height and diameter were taken for 40 trees of each progeny, arranged in four groups of 10 trees each, one group in each of the four replications of the experiment. The variability was broken down by the following analysis:

Source of Variation	*Degrees of Freedom*
Total	39
Replications	3
Within groups	36

The variability within groups is the best available estimate of the uniformity of the trees in each progeny. Four progenies were omitted because one or more trees were missing. A Bartlett chi-square analysis (5) was then made to determine whether these variances are independent samples from a single population. The values of χ^2 obtained were 387.26 for height and 364.65 for diameter. When these values of χ^2 are examined by the formula $\sqrt{2\chi^2} - \sqrt{2n - 1}$ = "normal deviate with unit variance" (4), it is found that, both for height and for diameter, differences in uniformity among the several progenies have exceedingly high significance (.000,000,001 level). It must be concluded that seedlings from some parent trees are inherently more variable than those from others.

Strictly speaking it is not good procedure to include some relatively uniform strains with other more variable ones in one analysis of variance because the standard error of the mean of a uniform strain would obviously be lower than that of a variable strain. The ordinary procedure would be to omit some of the most uniform and some of the most variable progenies, leaving a group in which all progenies show about the same degree of variability. Following this method it was found that after omitting 22 progenies in which the different individual seedlings exhibited high variability, and 17 progenies of exceptionally uniform seedlings, the χ^2 value for the variances for height of the remaining 126 progenies is 93.42. This indicates that the differences between the variances of the 126 progenies are no greater than may be expected as a result of random sampling. An analysis of variance of the heights of these 126 progenies, on the basis of randomized blocks, gives a value of F of 1.47, where 1.42 would indicate that height of differences between progenies are significant at the .01 point. This is not greatly different from the value of F for the whole 169 progenies as shown in Table I, namely, 1.59. It appears that the exclusion of the 22 rather variable and the 17 very uniform progenies has not affected the results materially and does not necessitate any change in the conclusions drawn. Similar computations for diameter of trunk could be made but in view of the results obtained for height, it is doubtful if the information gained would justify the labor involved.

The pooled standard error arrived at by use of all 169 progenies is theoretically too high for comparisons between uniform strains and too low for comparisons between variable strains. Of the 257 very highly significant differences in height listed in Table II, 44 involve one or the other of the 22 rather variable strains. Some of these would lose significance if tested by a more appropriate standard error. On the other hand differences involving the 17 uniform strains should be tested by a lower standard error than that arrived at by pooling all 169 progenies, and no doubt some very highly significant differences were overlooked. The same would be true for all characteristics studied. Thus, although individual comparisons might be questioned, there is no reason to doubt the main conclusion, that individual seedling progenies of tung exhibit very highly significant differences in growth characteristics.

SUMMARY AND CONCLUSIONS

1. Seed from 169 open-pollinated parent tung trees was planted in an experimental area in a lattice design. Data were obtained on germination of the seed, and on height, trunk diameter, and branching of the nursery plants at the end of the first season.

2. Analyses of variance show that differences between the progenies with respect to (a) germination, (b) height, (c) trunk diameter, and (d) percentage of branched trees are much greater than might be anticipated as a result of random sampling from a single population. It is concluded that the progenies differ inherently in the characteristics studied.

3. Bartlett's chi-square test shows that the variances for height and diameter, calculated separately for each of 165 progenies, are heterogeneous. It is concluded that these 165 progenies differ significantly in uniformity of these two characteristics.

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Combining Genetically Different Samples for Correlation Analysis

By L. F. Hough and E. L. Welker, *University of Illinois, Urbana, Ill.*

In studying data from several treatments or experiments by correlation analysis, there is frequently a desire to combine several samples in order to increase the number of cases, or show a relationship for the population as a whole. Such a situation usually results when there are relatively few observations in any one treatment, or when it seems expedient to try to bring out information relative to a particular point that had not been anticipated when the experiment was designed.

While examining the data for the individual progenies included in the paper by Dorsey and Hough (2) the opportunity presented itself to illustrate a precaution regarding the combination of samples

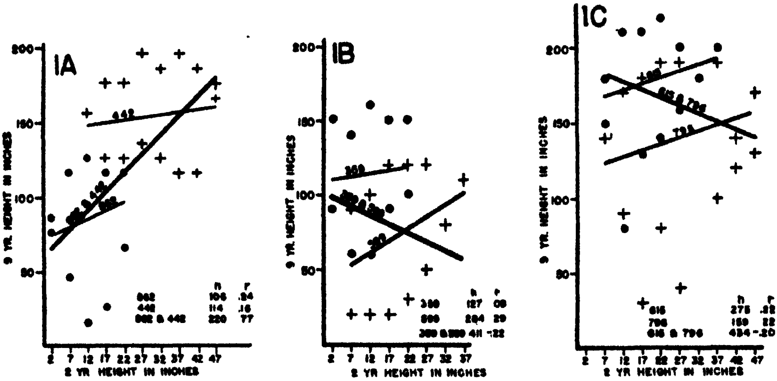

Fig. 1. Regression lines showing the effect of combining observations from genetically different samples for correlation analysis. 1A, The line 862 is the regression line for the progeny: 3188–3 (Rome Beauty x Grimes Golden) x Rome Beauty. The line 442 is the regression line for the 1914 progeny of: Rome Beauty x *Malus floribunda* (821).* The line 862 and 442 is the regression line resulting from the combination of the progenies. The dots and the plus signs represent the extreme values in progenies 862 and 422 respectively. 1B, The line 359 is the regression line for the progeny: Duchess x Shackleford, and the line 599 is the regression line for the progeny: *M. baccata* (807) x Jonathan. The line 359 and 599 is the regression line resulting from the combination of the progenies. The dots and plus signs indicate the extreme values in progenies 359 and 599 respectively. 1C, The line 615 is the regression line for the progeny: *M. baccata sanguinea* (813) x Collins, and the line 796 is the regression line for the progeny: *M. prunifolia* var. (19651) x Sops of Wine. The line 615 and 796 is the regression line resulting from the combination of the progenies. The dots and the plus signs represent the extreme values in progenies 615 and 796 respectively.

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*The species names and numbers included in this paper refer to the clons described by Crandall (1). Representative trees of these are still growing in the orchards devoted to Project 201 of the University of Illinois Agricultural Experiment Station.

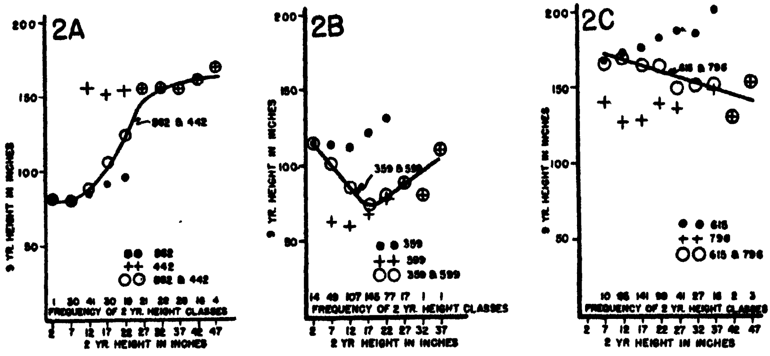

FIG. 2. Approximation curves showing three types of regression that may result from combining observations from genetically different samples. The progenies involved and the progeny numbers are the same as those described in Fig. 1. In every case the plotted points represent the average nine-year height for the 2-year-height class indicated.

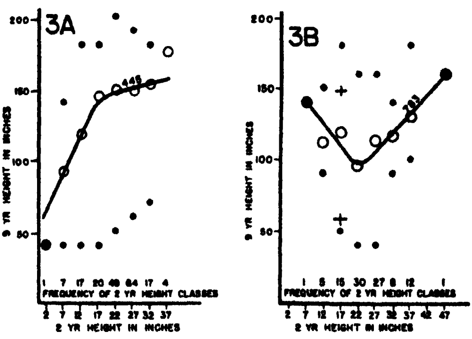

FIG. 3. Approximation curves showing two types of curvilinear regression of 9-year height on 2-year height in selected hybrid apple progenies. The dots and the circles indicate the extreme and the average values, respectively, for the 2-year height classes indicated. 3A gives the regression in progeny 445: Rome Beauty x Yellow Siberian Crab. 3B gives the regression in progeny 783: *M. sehideckeri* (19646) x Isham. The plus signs indicate the average values for the two widely separated 9-year height groups in the particular 2-year height class indicated.

suggested by Welker and Wynd (3) that must be considered in correlation analysis.

MARKED CHANGES IN CORRELATION AND STRAIGHT LINE REGRESSION

In Fig. 1A, with the scatter of progeny 862 in the lower left area of the graph and the scatter of progeny 442 in the upper right area of the graph, the regression line for the combined progenies joins the two scatter diagrams. This gives a much steeper slope and a much higher correlation coefficient that would be judged significant by the accepted statistical tests for the significance of correlation coefficients. A quite different situation may also occur as is shown in Fig. 1B. Here the scatter of progeny 359 is in the upper left area of the graph, while the scatter of progeny 599 is in the lower area of the graph and extends farther to the right. The regression line for the combined progenies again joins the two scatter diagrams. While the new correlation coefficient would also be judged significant by the accepted tests for statistical significance, the slope is changed from positive to negative!

The third situation illustrated in Fig. 1C also results in a complete reversal of slope. In this case both progeny 615 and progeny 796 have the same correlation coefficient for the relationship between 2-year height and 9-year height, the regression lines are very nearly parallel and their scatter diagrams overlap considerably. However, as in the first two examples, the relationship between the means for these two progenies is responsible for the pronounced change in the correlation coefficients from +.22 to —.20. The mean 2-year height of progeny 615 is less than that of progeny 796 while the mean nine-year height of progeny 615 is the greater, (see Table II of (2)). Their variances also differed.

Certainly neither the correlation coefficients nor the regression lines calculated from these combined progenies are reasonable. However, an inspection of the scatter diagrams for the separate progenies in each group indicates that the progenies are from different populations and therefore may not properly be combined.

CURVILINEAR REGRESSION AND HETEROGENEITY

The smoothed approximation curve in Fig. 2A for the regression of 9-year height on 2-year height in the combined progenies is similar to a "sigmoid growth curve". Since this is much the same as the approximation curve that would be obtained from the data in Table III of (2), it might be argued that this sigmoid regression line represents a fundamental relationship between 2-year and 9-year height for the genus *Malus*. However, this may not be concluded from the data because the regions of inflection as well as the slope of the different portions of the curve would be determined by the size and distribution of the scatter diagrams for the progenies that were chosen to make up the total population.

Nevertheless it is important to note that this is the general type of curve resulting from the combination of a population of small size at 2 years and 9 years with a population of greater height at 2 years and at 9 years. In this case it is obvious that the lower plateau is determined solely by the averages from progeny 862, and the higher plateau coincides with the regression line for progeny 442, while the averages of data from the low and high progenies determine the steeper portion of the curve.

A curve like that in Fig. 2B does not seem reasonable for the regression of tree height on seedling height. However, the cause of this unexpected slope becomes apparent from a consideration of the distribution of the progenies that were combined. Here the negative slope of the first part of the curve results from combining progeny 359 which was short at 2 years but high at 9 years with progressively more of progeny 599 which averaged taller at 2 years but shorter at 9 years. The positive slope in the rest of the curve coincides with the regression line for progeny 599 since the two progenies do not overlap in this region.

GENETIC IMPLICATIONS OF REGRESSION CURVES

As noted in (2), curvilinear regressions were observed in a few of the individual progenies and two of these are shown in Fig. 3. The similarity of the curves in Fig. 2A and 2B and those in Fig. 3 suggests that the genetic situations synthesized in Fig. 2A and 2B are comparable to those existing in the progenies illustrated in Fig. 3, so that the relationships known to exist in Fig. 2A and 2B might be used in interpreting the genetic significance of the curves in Fig. 3.

On this basis, the flattened upper portion of the curve in Fig. 3A is an indication that the group of seedlings which were concerned in this part of the curve represented a fairly homogeneous height group, that is these five 2-year height classes were all nearly alike with respect to the potential 9-year height of the seedlings included in them. Similarly the steeply sloping part of the curve in Fig. 3A may be taken as an indication that the seedlings concerned in this part of the curve differed among themselves with respect to their potential 9-year height, and that the shorter 2-year height classes had a smaller proportion of the potentially tall seedlings.

From what is known about the inheritance and expression of quantitative characters such as size, the discussion presented is in accord with a reasonable analysis of the genetic relationships shown in progeny 445. Furthermore the situation seems more obvious when illustrated by regression than it would from a frequency distribution where the only evidence of a departure from normality in the distribution of the 9-year height for this progeny is a skewness towards the taller height classes, (see Table II of (2)).

Judging from Fig. 2B, the curve in Fig. 3B also results from the combination of distinctly different groups of trees: one in which the seedlings were short at 2 years but made tall trees at 9 years, and another group in which the seedlings were taller at 2 years and ranged from much shorter to as tall at 9 years. An examination of the scatter diagram for this progeny supports this conclusion. The first observation, the mean, and the extremes of the 12-inch 2-year height class all indicate that these shortest six seedlings were taller than the average for taller 2-year height classes, for example the 22-inch class which had the largest number of observations. The 17-inch 2-year height class is even more exceptional. It is made up of five trees below 80 inches with an average height of 59 inches at 9 years, and 10 trees above 130 inches with an average of 148 inches at 9 years. Clearly then, progeny 783 is made up of two groups of seedlings which differed considerably in their 2-year 9-year growth relationships. This situation would be difficult to detect from a frequency distribution.

In both Fig. 3A and 3B curvilinear regression appears to be a method of illustrating the genetic growth relationships present in these progenies which result in their heterogeneity. However, the regression shown in Fig. 2C is a result of combining unlike samples which seems best expressed by a negatively sloping straight line. While this combination results in a frequency distribution that is skewed toward the shortest 2-year height classes, and a frequency distribution that is skewed toward the tallest 9-year height classes, neither of these facts would indicate the genetic heterogeneity present in the combination which results in the apparently illogical negative association between 2-year height and 9-year height. Thus it is evident that distinctly different samples may be combined to give a straight line regression, so that merely determining the form of the regression is not proof of homogeneity.

SUMMARY

Correlation coefficients calculated for combinations of data obtained from two different sources may be invalid. If the two groups come from distinct parental populations in which means and variances differ, a correlation calculated from the combined data may be either larger or smaller than the correlation in either population. It may even be that while the components both have correlations of one sign, a combination of the two may exhibit a correlation of the opposite sign. Finally, non-linear regression may result from combining data from separate populations or from two portions of the same populations. It is clear that the consideration of the components as separate samples will avoid possible incorrect interpretation of correlation and regression.

In cases such as those presented, curvilinear regression or even apparently unreasonable straight line regression may be taken to indicate the possibility of the presence of genetically different groups within the sample.

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The "Tristeza" Disease of Sour-Orange Rootstock[1]

By H. J. WEBBER,[2] *University of California, Citrus Experiment Station, Riverside, Calif.*

WHILE studying the citrus industry in South Africa in 1924–25 (10), the writer made rather extended notes on the failure of the sour orange as a rootstock for the orange in all parts of that country as far north as southern Rhodesia. The trouble or malady had been given no distinctive name, and at that time was unknown elsewhere. It has since appeared in Java, Argentina, and Brazil where it is reported to be causing severe damage. Moreira (7), who has studied the disease in Brazil, referred to it as the "tristeza" of citrus. This is a short word (Portuguese for melancholy or sadness, and the same in Spanish) characterizing the trouble and may well be used in all languages as the standard name for the disease.

It may be stated further that regardless of the cause of the trouble, whether it is due to a parasitic fungus, a bacterium, a virus, a toxic substance, malnutrition, or climatic influence, it is entirely proper to call it a disease. Any adverse condition is a disease in its effect on the plant, if it produces a deranged or morbid condition.

The tristeza disease, so far as known to the writer, was first noted in South Africa, and the following is an outline of the early historic data.

Up to near the end of the 19th century, citrus-growing in South Africa employed mainly seedling sweet oranges and tangerines or trees propagated from good seedlings by layering; and a scattering of trees of various sorts grafted principally on Rough-lemon stocks. Grafted or budded trees at that time had been very little used in South Africa and the industry was small. In the last decade of the century the loss from foot rot, or collar rot as it is there called, became so serious that a government commission appointed to study the situation urged that growers use only trees worked on sour- or Seville-orange stocks. In 1896 the Cape Agricultural Department issued a circular urging the use of the sour orange and stating that "so much has been written on this subject, and the universal practice of European countries has so emphatically endorsed the wisdom of using the Bigarade or Bitter Seville orange as the healthiest and strongest citrus stock, that little additional remark need be made here" (4). As a result of this consistent recommendation of the sour-orange stock by government agencies, nurserymen found it necessary to use only sour-orange stock, as otherwise they could not sell their trees. Many thousands of trees were worked on sour stocks, sold, and planted. In a few years all of these had died, but it was long before the cause of their failure was definitely attributed to the use of sour stock. Another commission inquiring into the failure of citrus trees 10 years later found that there were healthy 50-year-old orchards on Rough lemon, and that stock soon came to be used almost exclusively (6).

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[1] Paper No. 495, University of California Citrus Experiment Station, Riverside, California.

[2] The writer is indebted for many suggestions to Dr. W. T. Swingle, of the U. S. Department of Agriculture, and to Dr. H. S. Fawcett, of the University of California Citrus Experiment Station.

In 1924, Davis wrote (4), of South Africa: "The *'Bitter Seville,'* and *'Florida Sour'* make, as seedlings, exceptionally fine trees. About 12 kinds of Oranges, Naartjes (mandarins), and some Lemons were budded on these stocks, and at the end of 3 years, there was not one of them alive. The soil was a somewhat sandy medium red loam, 20 feet deep. In one instance where the bud had died, the stock remained alone and grew into a remarkably fine tree." Davis also described an earlier experience (about 1899) in which three varieties of lemons and some Washington Navel orange trees, all budded on sour-orange stocks, were planted in Cape Colony. The oranges grew well the first year, but growth ceased the second year and in the third year all died. The lemons, however, grew well and were reported as still living and profitable in 1924.

Davis thus indicated that oranges and mandarins on sour stocks failed in a few years, but that in one case lemons on sour stock were entirely successful.

The results of the writer's study of this subject in South Africa (10), written before Davis's publication was available, brought out the following points:

1. The writer stated: "All of these groves of orange on Seville stocks proved failures and have gradually disappeared, so that the writer has found difficulty in finding even a few trees here and there of moderate age, none over about 20 years, which are still living, and these are much dwarfed and worthless as producing trees."
2. The writer called attention to the wide range of soils on which the disease was fatal, and to the fact that on similar soils in other countries trees of the same combination were successful.
3. The use in Africa of uncongenial strains of the sour orange was excluded by the writer as a possible cause of the disease because he had examined several 2- to 10-acre plantings of imported trees in several localities, of Valencias and Washington Navels, budded on sour stocks in California and Florida, in which all of the trees, 2 to 5 years after planting, were dead or in various stages of collapse. Many such trees were dug and carefully examined, but no evidence of any causal agent could be observed. Again considering the number of sources from which the sour-orange seeds came, that were used to grow stocks in South Africa, it is inconceivable that all would be incompatible or uncongenial.
4. The writer pointed out that trees of the sour or Seville orange, grown as seedlings or budded on Rough lemon, appeared to be vigorous, healthy, and of normal size and productiveness. This was observed in a number of localities. The same was found also to be equally the case with the sweet orange and the mandarin.
5. No cases of grape fruit and mandarin varieties propagated on sour orange, were found by the writer. The common testimony of growers was that these combinations were entirely unsatisfactory, but whether or not in equal degree could not be determined with certainty, as the cases of actual experience were few.

6. The testimony of growers, and the observations of the writer indicated that lemon varieties worked on sour-orange stocks were not subject to this disease. Several small lemon groves, 20 or more years old, were studied in Cape Colony, and yard trees in many other places, and none of them exhibited any signs of collapse, though not all of them were in good condition. It would appear that lemon on sour is not subject to the disease.

7. The writer's observations also indicated that the Rough lemon and the sweet orange used as stocks for varieties of the sweet orange and the mandarin were not noticeably affected by the disease. It was thus indicated that these stocks are immune or in some degree resistant to the disease.

Powell (12) discussed the failure of sour-orange stocks in South Africa, but cited no additional observations other than the following: "When imported trees that are budded on sour stock are *inarched with small Rough lemons they develop normally.*"

The next study, of what appears to be the same disease, was made by Toxopeus (8, 9) in Java. In his investigations he demonstrated that the buds of the sweet orange united normally with the sour stocks and that the sprouts developed and grew well at first, but soon showed symptoms of decline and usually died within 8 to 12 months. The sweet-orange varieties used in his experiments included Valencia, Washington Navel, and Hamlin, sorts that succeed well on sour orange in most countries. The "Japanese citron" (*C. nobilis* x *C. medica* ?), which grows fairly well on sour stocks in Java, was used as an interstock between the sour stock and the sweet-scion variety, but it had no effect in prolonging longevity. By using all possible combinations of the sweet, sour, and "Japanese citron" either as stock, interstock, or scion, it was found that the failure of the combination occurred only when the scion or top was sweet orange and the stock or interstock was sour orange. The budding of both sweet orange and "Japanese citron" into the same sour-orange stock resulted in the death of the plant, but the inarching of sweet orange with both sour orange and "Japanese citron" resulted in the death of the sour orange only. Toxopeus thus concluded that the sour-orange stock does not injure the sweet orange, but that the sweet-orange scion produces some substance injurious to the sour stock. This apparently indicates the source of the injury, but as yet no explanation has been found as to why such contrary results are produced in different locations.

Toxopeus (9) eliminated soil differences as a factor in the cause of the disease because in "Java with its numerous soil types, the combination would be expected to succeed at least in some places, and some success should be gained by manurial treatments." Also because of the known distribution of the disease, he eliminated the lack of a rest period, or the length of day as causal factors.

Marloth (6), in studies at Nelspruit, Transvaal, made tests with eight different varieties of sour orange used as rootstocks and reported that after 7 years of experimentation he had been unable to produce good trees of any "sweet orange or tangerine variety on sour stocks. Some degree of success was obtained with grapefruit and tangelo varieties, and no difficulty was experienced when lemon varieties were used."

Marloth also reported.that "in cases where the stock has grown out after the death of the scion remarkably healthy and vigorous sour orange trees have resulted", and also that diseased trees of sweet orange on sour "when inarched in time with rough lemon seedlings, the top grows but the Seville (sour) stock dies nevertheless." Marloth states that when the Sampson tangelo is used as a stock for the sweet orange in South Africa, "its behavior is very similar to that of the sour orange when used as a stock". Contrary results with the Sampson Tangelo have been reported by Moreira (7) in Brazil.

Marloth suggested that the failure of the sour orange as a rootstock in South Africa may be a problem of mineral nutrition but gave no definite data in support of the hypothesis.

Recently it is reported that in Argentina and Southern Brazil the same or a very similar trouble has appeared on sour stocks budded to sweet orange, grapefruit, or mandarin varieties. Here, according to Camp (3), the sour orange, when grown as seedlings, is not visibly affected, and trees of lemon varieties on sour are apparently uninjured or at least not seriously influenced. All sours grafted to orange, grapefruit, or mandarin die, but if a sour sprout gets started from the root with sour foliage, it grows well. Also according to Camp, lemons on sour stocks do very well and peculiarly when sweet-orange trees on sour stocks start to decline they can be top-worked to lemon successfully; the root system recovers and the trees are excellent, both from the tree standpoint and production.

The disease appeared in Argentina about 1931 and in Brazil about 1937. Numerous papers have appeared in these countries describing the disease and its spread; and researches on its cause and control, the writer understands, are being vigorously prosecuted. Only a small portion of these publications are available to the writer for consultation, but so far as can be determined from those available, the characteristic features of the disease conform almost entirely with those observed in Africa.

The most thorough treatment on all phases of the disease thus far published is contained in Bitancourt's papers describing the disease in Corrientes, Argentina (1, 2). He gives a list of susceptible, doubtful, and resistant combinations and of species grown as seedlings, as observed by him in Corrientes, and these conform entirely with the data from Africa. All ages of trees were found to be affected.

As cited above, Moreira (7) referred to the malady as the "tristeza" disease and described its rapid spread. All over Sao Paulo, sweet oranges on sour stocks almost all die, some very rapidly, but lemons on sour do not. He stated that Thornton tangelo as a stock is very susceptible, but that Sampson tangelo is completely resistant. This is contrary to the statement of Marloth, who found in Africa that Sampson tangelo as a stock reacted very similarly to the sour orange (6).

As contributing to an understanding of this obscure disease, the following discussion may be helpful:

1. The idea that the cause of the trouble is due to the incompatibility

of the sour stock with the sweet orange, mandarin, or grapefruit budded on it, as stated above, may be eliminated as a probable cause. The millions of successful trees of these combinations of stock and scion in many parts of the world, clearly testify to the full congeniality of these unions.

2. The particular variety or kind of sour orange used as the stock in Africa and other parts of the world where the disease occurs, may also be eliminated as the probable cause of the trouble, as stated above. This conclusion is primarily based on the fact that large numbers of trees budded in California and Florida on types of sour orange known to be congenial and successful were imported into Africa as budlings (budded trees) and there, when planted, regularly succumbed to the disease. It is certain that these trees, if they had been planted in California or Florida, would be alive today.

3. The Toxopeus theory. As this predicates the development in the sweet-orange top of some substance that is lethal to the sour-orange root, it necessitates that we assume this substance to be formed only in those localities where the trouble occurs, and not elsewhere. This is evident as the sour orange has been a dominant stock in most citrus regions for at least 75 years, and has been very successful.

It should be remembered that the particular products manufactured in any plant are commonly characteristic of that plant, and certainly very generally are produced in like degree and comparative quality in other countries and environments (note rubber, cincona, cloves, ginger, pepper, nutmeg, and so on). The writer has been unable to learn of any case where a plant introduced into another country produced a different and novel constituent regularly. One plant through mutation might change, but certainly not all plants of the kind would change suddenly. It is thus inconceivable to the writer that sweet-orange varieties in Java and Africa would 'all be so affected as to produce some new and different substance, under all the variable conditions there existing, that was capable of causing the death of stocks which in other countries are normally fully congenial and successful.

4. Soil and climatic conditions. Probably the first thought of every one who has studied the tristeza disease in the field is that it may be caused by some peculiar combination of soil and climatic conditions. This possibility cannot yet be dismissed as a possible cause but, as pointed out by Toxopeus, it does not seem probable. In Africa the death of the trees occurred on all types of soils, sterile and rich; on hills and slopes and in deep rich alluvial river valleys; on sands, clay loams and loams; on virgin soils newly cleared and on old long-tilled areas. Also in Africa the disease, so far as could be learned, was equally severe in sections of high and low rainfall; of summer and winter rainfall; under natural rainfall and under irrigation. The soils of affected sections also ranged from near sea level up to 4000 feet or more in elevation. The occurrence of the disease apparently in the same degree of severity under these varying conditions seems to the writer to probably preclude soil and climatic conditions as the primary causal agent.

Further evidence, though negative in nature, against soil and climatic conditions as a possible cause, is furnished by the fact that the disease is not yet known to occur in the older citrus sections, such as Italy, Spain, Florida, California, Palestine, Egypt, and Algeria, all countries in which the sour-orange rootstock has been widely and extensively used. The disease is so destructive that it certainly would have been noted had it acted as in Africa, Argentina, and Brazil.

5. Deficiency in minor elements. That the disease is caused directly by the lack of, or excess quantities of, any minor element of nutrition or toxic material in the soil, does not seem probable because of the successful growth of all of the species concerned as seedlings grown on their own roots, or when budded on other stocks. This improbability is furthered by the reasons mentioned above under the preceding heading.

6. Virus origin hypothesis. Bitancourt (1) stated that some virus latent in the sour orange and virulent in the sweet orange, which is transmitted through the bud union to the scion, would explain practically all the manifestations of the disease. This hypothesis, however, does not seem to conform with the facts determined by Toxopeus (9), that sour on sweet stocks grows successfully and that sweet when used as an interstock between sour and "Japanese citron" remains uninfluenced. It furthermore would not account for the death of the sour stocks when the sweet-orange tops are saved by inarching with "Japanese citron" or Rough lemon.

Toxopeus (9) concluded from his experimental tests that "In the writer's opinion this result can be explained only on the supposition that some strongly toxic action occurs from something manufactured in the leaves of *Citrus sinensis*." Toxopeus' results were clear-cut and definite and constitute the only careful experiments thus far reported. The reactions recorded, it would seem, cannot be questioned. The probability of this lethal agent's being a normal product of sweet-orange metabolism is discussed above. It would seem that if it is some constituent in the sweet-orange top that causes the death of the sour stocks, as suggested by Toxopeus, it must be something foreign to the normal metabolism of the sweet orange, that is, something extra, something acquired in the location where the trouble occurs. Carrying this thought farther, it would seem that the only material that could be acquired by the plant that could be expected to give such a reaction as indicated, so far as we now know, would be some virus that might be carried to the sweet orange by an unknown vector to which the sour orange is repellent, a virus not noticeable in its effect on the sweet orange but which, when introduced into the sour orange, is toxic to that species. If, however, Marloth (6) and Camp (3) are correct in their observations that sprouts from the stocks when they happen to get started, continue to grow, then it would seem that the introduction through the sweet top of a virus, lethal to the sour orange, could not be considered as a correct interpretation, for certainly such sprouts would be invaded by the virus.

A more serious difficulty must be overcome, however, in explaining how it can possibly be a virus disease when Camp states positively that trees of sweet on sour when they begin to decline can be topworked to lemon and will then grow into successful commercial trees.

The hypothesis that the disease is caused by a virus would also from the known conditions require that the mandarin and grapefruit attract the vector as does the sweet orange, and that they can be carriers of the virus without themselves showing visible influences of its presence. This seems to stretch the imagination rather far, but we have a similar case in the virus that causes the scaly-bark disease of the sweet orange, mandarin, and grapefruit. Fawcett (5) has shown that this virus may be present in the sour orange or the lemon without causing visible injury to the growth of production, but that if such trees are budded to sweet orange or other susceptible varieties, the disease is transmitted to the scions, which are seriously injured.

In the various experimental propagations made by Toxopeus, using sweet orange, sour orange, and the unaffected "Japanese citron" in all possible combinations as tops, stock, and interstock, it was demonstrated that the only injurious and lethal combinations among the nine possible ones, were those where the sweet orange was used as the top or foliage part. The sweet had no injurious influence when used as the stock or the interstock.

It seems to the writer more plausible, therefore, to assume that the disease is due to a virus, and then the simple assumption *that the foliage of the sour orange and the lemon produces regularly and normally some product of metabolism that inhibits the action and development of the virus* would explain all the difficulties now experienced in attributing the disease to a virus.

If this is assumed as correct, then sour on sweet would be healthy, while sweet on sour would die, which is the case; also sprouts from the sour stock if they developed foliage would be expected to grow without injury, which according to both Marloth and Camp is true; also if trees of sweet on sour are top-worked to lemon before they decline too far, then as soon as the sweet foliage is removed and the lemon foliage develops, the tree would be expected to recover, as it is known to do; also trees of sweet on sour inarched with resistant Rough lemon or "Japanese citron" would be expected to recover, and they do; but the original sour stock still supplied by sweet-orange foliage should die, and it does. Wherever the sweet-orange, mandarin, or grapefruit foliage forms the top, the virus would be expected to continue its activity, and apparently this is the case.

A variation of this interpretation, suggested to the writer by one of his associates, Dr. L. C. Cochran, is that the conditions can be equally well explained by assuming that the virus has tissue specificity for the leaves of the sweet orange, mandarin and grapefruit and develops there a toxin or substance which when translocated down is lethal to the sour stock. If the virus can infect sour orange, it fails to produce in the leaves of this stock substances which are toxic to sour-orange tissue. This interpretation is similar to the hypothesis given by Rawlins and Parker (11) in explaining the action of the buckskin virus in sweet cherry on mahaleb root stock.

This interpretation necessitates two assumptions: (a), that the tissue of the sour orange and the lemon do not possess toxin production specificity for the virus, or are immune to its attack; and (b), that the presence of the virus in leaves of sweet orange, mandarin, and grapefruit produces a toxin lethal to the two immune species. It seems more reasonable to the writer and more in harmony with known principles to assume merely that the sour orange and lemon are immune because they develop in their normal metabolism some product that renders them immune to the virus. In any case either interpretation is dependent on the assumption that the disease is of virus origin.

The fact that some citrus species manufacture products known to render them resistant to various diseases, while other nearly related species do not, is well known, and needs no confirmation. This is the case with virus diseases as well as with fungus and bacterial diseases. The food products and minor products of metabolism produced in the sweet orange are well known to be different in many respects from those produced by sour orange or by lemon. It is no strain on the imagination, therefore, to predicate that some substance developed in the foliage of sour orange and lemon inhibits the effect of the virus, or prevents its development.

Of all of the suggestions that have been considered, the virus hypothesis seems to the writer to be the only one that cannot be considered at this stage as improbable. It should be recognized that the injurious influence may be exhibited only in or on the roots, somewhat as the lesions of scaly-bark show primarily only on the stems or in the leaves. The extension of the disease from country to country and from province to province in time of appearance, strongly suggests the spread of an infectious disease.

In view of the fact that many millions of citrus trees of all ages throughout the oldest and most productive citrus regions of the world, especially Italy, Spain, Florida, and California, are on sour-orange stocks, the determination of the cause of the trouble is of major importance. It is an obscure disease which seems to be spreading. It was first recognized in South Africa about 1910, in Java in 1928, in Argentina about 1931, and in Brazil in 1937. In all of these countries, according to reports, it is very destructive. Vigorous steps should be taken to discover the cause of the malady and to determine how it can be prevented. Millions of trees are propagated on sour-orange stocks, and the destruction of all of these trees would constitute a major calamity.

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Red Raspberry Breeding in Oregon[1]

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RED raspberry breeding has been carried on at Corvallis, Oregon since 1929 (1). The majority of the 6,425 seedlings which were planted fruited. About 40 of the most promising selections made between 1934 and 1938 have been retained for further testing.

Crosses Between Varieties

Of the principal crosses made from 1929 to 1941 (Table I), Viking x Lloyd George produced the highest percentage of seedlings that were rated excellent in the frozen-pack and canning tests during two or more seasons. The selected seedlings of Viking x Lloyd George generally bore large-sized firm berries of high quality, especially suited for canning and frozen pack. The canes are vigorous, hardy, tall but very stocky, and quite productive.

TABLE I—Principal Raspberry Crosses Made From 1929 to 1941, With the Number of Seedlings Planted and the Percentage Selected From Each Cross

Cross	Number of Seedlings Planted	Per Cent Selections Made	Per Cent Selections Excellent in Frozen Pack	Per Cent Selections Excellent in Canning	Per Cent Selections Remaining on trial
Chief × Newburgh	66	1.5	0.0	0.0	0.0
Chief × Lloyd George	556	6.7	0.7	0.0	0.2
Cuthbert × Lloyd George	616	12.0	1.8	1.9	1.6
Latham × Lloyd George	134	0.7	0.0	0.0	0.0
Lloyd George × Chief	375	5.3	0.0	0.3	0.3
Lloyd George × Cuthbert	694	6.3	0.3	0.4	0.9
Lloyd George × Newburgh	62	9.7	0.0	0.0	0.0
Lloyd George × Ranere	82	2.4	0.0	0.0	0.0
Newburgh × Lloyd George	449	15.8	1.3	0.7	1.1
Newburgh × Chief	84	8.3	0.0	0.0	0.0
Ranere × Lloyd George	121	10.7	1.6	0.8	0.8
Viking × Lloyd George	252	17.1	4.0	2.4	5.1
U. S. No. 9 (Latham × Ranere) × Lloyd George	142	0.7	0.0	0.0	0.0

The selected seedlings of Cuthbert x Lloyd George and Lloyd George x Cuthbert produced more and taller canes than those of any other cross. In fruiting habit and in hardiness they resemble Cuthbert, though a few appear to be more hardy than Cuthbert. The fruits of these selections have the same high quality when fresh, canned, or frozen as does the fruit of Cuthbert. However, most of the selected seedlings produced berries of small size (Table II).

The cross Newburgh x Lloyd George resulted in the largest percentage of selections that produced large berries. The berries of these selections were also firm and attractive in appearance, either fresh, in the frozen

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[1] The small fruit breeding work is a cooperative project between the Division of Fruit and Vegetable Crops and Diseases, U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, and the Oregon Agricultural Experiment Station.

TABLE II—RASPBERRY SELECTIONS CLASSED ACCORDING TO SIZE OF BERRY IN 1940

Cross	Number Selections	Per Cent With Large Berries	Per Cent With Medium Berries	Per Cent With Small Berries
Newburgh × Lloyd George	32	66.6	27.3	6.1
Viking × Lloyd George	20	47.8	26.1	26.1
Lloyd George × Chief	15	12.6	31.2	56.2
Cuthbert × Lloyd George	34	8.3	30.6	51.1
Chief × Lloyd George	20	4.8	47.6	47.6
Lloyd George × Cuthbert	38	0.0	28.6	71.4
Lloyd George × Ranere	2	0.0	50.0	50.0
Ranere × Lloyd George	9	0.0	11.1	88.8

pack, or canned. Their dessert quality, though not equal to that of fruit of the Viking or Cuthbert crosses, was, however, above average. The canes of plants of this cross are not usually so tall as those of Cuthbert x Lloyd George nor so stocky as those of Viking x Lloyd George, but tend to be somewhat willowy and branched. Because of their short internodes, many buds, and large berries, these selections are usually highly productive.

The plants of Ranere x Lloyd George seedlings were generally small, with short canes. The selections are mostly fall bearing and produce relatively small berries. Although most of the selections of this cross have high dessert quality, only a few produce berries large enough for commercial purposes.

The selections from crosses of Lloyd George with Chief, Latham, and U. S. No. 9 were generally hardy and productive, but their berries were usually soft, light red in color, and acid. Many light red but acid seedlings of Chief x Lloyd George were selected (Table I), but the

TABLE III—PRINCIPAL CROSSES FRUITED IN 1942 AND SELFED OR OPEN-POLLINATED SEEDLINGS

	Number of Seedlings Planted	Per Cent Selections Made
Principal Crosses Fruiting in 1942		
Newburgh × Pynes Royal	69	1.4
Taylor × Red Cross	165	0.0
Oregon 93 (Lloyd George × Plum Farmer) × Oregon 309 (Ranere × Lloyd George)	278	1.4
Oregon 142 (Cuthbert × Lloyd George) × Oregon 273 (Ranere × Lloyd George)	171	5.3
Oregon 142 (Cuthbert × Lloyd George) × Oregon 379 (Newburgh × Lloyd George)	132	0.8
Oregon 273 (Ranere × Lloyd George) × Oregon 142 (Cuthbert × Lloyd George)	62	0.0
Oregon 273 (Ranere × Lloyd George) × Oregon 302 (Cuthbert × Lloyd George)	11	18.2
Oregon 420 (Newburgh × Lloyd George) × Cuthbert	157	14.0
Selfed or Open-Pollinated Seedlings		
Lloyd George open	162	4.9
Lloyd George selfed	57	5.3
Newburgh selfed	171	4.4
Cuthbert selfed	81	2.5
Oregon 60 (Lloyd George open) selfed	102	2.0
Oregon 140 (Cuthbert × Lloyd George) selfed	97	4.1
Oregon 141 (Cuthbert × Lloyd George) selfed	75	2.7
Oregon 189 (Cuthbert × Lloyd George) selfed	110	0.9
Oregon 340 (Newburgh × Lloyd George) selfed	71	2.8
Oregon 420 (Newburgh × Lloyd George) selfed	234	0.4
Oregon 542 (Newburgh × Chief) selfed	42	4.8

fruits of only a few were promising in the frozen pack or canning tests. The light red color of the fresh fruit often became unattractive after processing, and the acidity was always objectionable.

Only one seedling of Newburgh x Pynes Royal was selected. Although the berry size of seedlings of this cross was the largest of any (Table IV), the berries were generally of poor flavor. No selections were made from the Taylor x Red Cross (Table III) as all seedlings had poor dessert quality.

TABLE IV—Weight of Berry of Raspberry Seedlings Fruiting Between 1936 and 1942 (Average Weight in Grams per Twenty Berries From Each Seedling Plant)

Cross	Year in Which Seedlings Fruited	Number of Seedlings Fruiting	Average Weight Per Twenty Berries (Grams)
Newburgh × Pynes Royal	1942	27	77
Oregon 420 (Newburgh × Lloyd George) × Cuthbert	1942	60	61
Newburgh × Lloyd George	1936	100	60
Newburgh × Lloyd George	1937	39	60
Viking × Lloyd George	1937	167	57
Newburgh × Chief	1937	21	58
Newburgh × Chief	1936	39	54
Viking × Lloyd George	1936	100	51
Latham × Lloyd George	1936	134	51
Oregon 93 (Lloyd Geo. × Plum Farmer) × Oregon 309 (Ranere × Lloyd George)	1942	33	50
Chief × Lloyd George	1937	25	49
Oregon 140 (Cuthbert × Lloyd George) selfed	1942	11	48
Oregon 142 (Cuthbert × Lloyd George) × Oregon 273 (Ranere × Lloyd George)	1942	48	47
Lloyd George × Chief	1937	71	46
Lloyd George × Chief	1936	98	46
Cuthbert × Lloyd George	1936	78	45
Chief selfed	1936	6	45
Lloyd George × Chief	1937	30	45
Oregon 142 (Cuthbert × Lloyd George) × Oregon 379 (Newburgh × Lloyd George)	1942	31	45
Cuthbert × Lloyd George	1937	12	44
Lloyd George × Cuthbert	1937	74	43
Latham × Viking	1936	8	42
Newburgh selfed	1936	7	42
Ranere × Lloyd George	1937	17	41
Oregon 273 (Ranere × Lloyd George) selfed	1942	10	41
Chief × Latham	1936	8	39
Lloyd George × Cuthbert	1938	41	37
Lloyd George × Ranere	1936	37	36
Ranere × Lloyd George	1936	40	35

Crosses Between Selections

Additional selections have also been made from the progenies of crosses between the earlier selections, and of crosses between the earlier selections and named varieties (Table III). An outstanding cross, as measured by number of seedlings selected, was Oregon 420 (Newburgh x Lloyd George) x Cuthbert. The seedlings of this cross were especially vigorous and productive and the fruit averaged as large as that of seedlings of Viking x Lloyd George and of Newburgh x Lloyd George and was much larger than fruit of Lloyd George x Cuthbert. In preliminary tests made in 1942, the selections from Oregon 420 x Cuthbert were promising for frozen pack and canning.

The selections from selfed varieties and from selfed selections have not been outstanding. The earlier selfed selections were discarded because of plant weaknesses. The selfed selections made in 1942 are vigorous at the present time and some may have commercial value.

DISCUSSION AND SUMMARY

Lloyd George has proved to be a satisfactory parent in red raspberry breeding in Oregon, just as in Washington (2) and New York (3). In Oregon so far, Viking, Cuthbert, and Newburgh have been the most suitable varieties to cross with Lloyd George. Viking x Lloyd George combines large berry size, firmness, and good quality with vigor of plant and productiveness. The selections from Cuthbert x Lloyd George and from the reciprocal cross are also vigorous and productive and the quality of their fruit seems even better than that of selections from Viking x Lloyd George. However, the berries are generally small in size and the canes are not fully hardy. The Newburgh x Lloyd George seedlings bore large berries and many were productive, but the selections from this cross are relatively acid and, though good, do not have the best flavor. One selection has, however, been named Willamette and introduced.

The large number of promising seedlings that have been obtained indicate that crossing selections from the F_1 population with a variety or crossing among promising F_1 selections may be effective methods of obtaining desirable new varieties. The cross Oregon 420 (Newburgh x Lloyd George) x Cuthbert gave the most promising selections. Crosses between two seedlings which had Lloyd George as one parent have not been promising.

Results from selfing are in general agreement with those of Slate (3) in that populations of selfed seedlings were generally weak. However, among seedlings from selfing some selections for high vigor may yet prove to have value.

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Pruning of Low-Bush Blueberries

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PRUNING of the low-bush blueberry, *Vaccinium angustifolium,* every two and every three years was reported (1) in 1939. The present report presents the results of a study to see if plants could be cut and covered with soil to preserve the organic matter which is lost in burning. Another study was also made to see if newly set plants would spread faster if burned at the time of setting and one year later than if burned only at the time of setting.

Plants from one clone were asexually propagated in 1939 and set in 1940. A quarter of the plants was cut as close to the ground as possible immediately after setting. Another fourth was similarly cut and the stubble covered with soil. This was done as cut plants have a large number of aerial branches in contrast to the few subterranean branches which develop when plants are burned. For comparison a fourth of the plants was burned after setting and a like number was burned and then covered with soil. Cutting was the poorest method of pruning and burning was the best. Cut plants covered with soil spread more and had more stems than uncovered plants. On the other hand burned plants spread less and had fewer stems when covered with soil, Table I. Plant spread was the number of quadrat units which the underground stems occupied.

TABLE I—Effect of Different Methods of Pruning on Spread and Number of Stems of Blueberries

Treatment	Spread	Number of Stems
Cutting	4.8	58.0
Cutting plus soil	6.2	95.0
Burning	10.5	171.2
Burning plus soil	9.0	104.2
Difference necessary for significance	5.6	43.6

While the past investigations had shown that burning should not be practiced more frequently then every three years from the standpoint of yield, there were some indications that frequent burning might increase the spread of plants. To study this, eight selections (eight plants of each) were burned after setting (1940) and a year later. Two groups (A and B) each with eight plants of each of the selections were burned only at the time of setting. Burning one year

TABLE II—Effect of Burning on Spread and the Number of Stems of Blueberries

Treatment	Spread			Number of Stems		
	1940	1941	1942	1940	1941	1942
Burned when set and 1 year later	4.4	4.8	10.2	24	43	172
Burned when set A	4.7	5.9	11.5	25	90	193
Burned when set B	5.1	6.3	12.4	28	107	202
Difference necessary for significance	1.0	1.1	1.6	6.6	23.5	40.0

after setting reduced the spread slightly but the difference was significant in some cases. Burning one year after setting reduced the number of stems significantly in 1941 but the following year there was not a significant difference, Table II.

The results of these studies show that burning is the best method of pruning and that the frequent use of burning does not increase plant spread.

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A Second Report on the Best Parents in Strawberry Breeding[1]

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THIS paper is an attempt to estimate the breeding value of certain strawberry varieties by comparing the percentages of promising seedlings selected from various populations for further testing. This method is not exact, but when enough populations of considerable size are involved some evidence is obtained as to the possibilities of certain varieties as parents.

Seventy-four crosses, of which nine were reciprocals, produced 11,761 seedlings which fruited during the years 1936 to 1942, and of these 292 or 2.48 per cent were selected for either further testing or use in breeding. In some populations seedlings were saved for breeding purposes only because of certain desirable characteristics, but these were not numerous enough to invalidate this method of evaluating the breeding value of a variety.

The value of Howard as a parent in breeding strawberries has been reported in a previous paper by the author (1) and by Darrow (2). Crosses made since the previous report have given similar results and support the statement made then that Howard was an outstanding parent. In this report the cross Sparkle x Howard was especially good, but some promising seedlings resulted from the cross with Fairfax although the percentage selected was low. In the cross with Chesapeake no seedlings of merit were obtained although selections were made for further crossing.

Fairfax has been another outstanding parent and has transmitted its high quality, attractive appearance and dark color to a high proportion of its progeny. The crosses with Dresden, Aberdeen, Howard and Wyona were especially satisfactory. Crosses of Fairfax with Vanrouge, Cato and Marshall were unsatisfactory.

Sparkle was an unusually good parent in five of the six combinations tested and transmitted its quality and attractive appearance to many of its seedlings. Some very handsome fruit resulted from the cross with Beacon, but the plants were rather unproductive. The crosses with Dresden and Howard were especially good.

New Jersey 303 was used in only two crosses, but the percentage of seedlings selected was rather high.

Julymorn was used in two crosses to obtain varieties adapted to preservation by freezing. Julymorn x Vanrouge produced one of the poorest populations of strawberries fruited at Geneva but Sparkle x Julymorn was much more promising.

Catskill was used in only four combinations, and no seedlings of outstanding merit were produced.

Clermont has given very few selections in the combinations reported

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[1] Journal Paper No. 546, New York State Agricultural Experiment Station, Geneva, New York, February 20, 1943.

TABLE I—NUMBER AND PERCENTAGE OF SELECTIONS FROM VARIOUS STRAWBERRY CROSSES

	Number Seedlings Grown	Percentage Selected
Crosses involving Aberdeen:		
Aberdeen × U.S.D.A. 1021	262	4.6
Aberdeen × Fairfax	108	4.6
Aberdeen × Dresden	54	0.0
Aberdeen × N. Y. 9270	30	0.0
Clermont × Aberdeen	61	3.2
Dresden × Aberdeen	389	1.3
Crosses involving Beacon:		
Beacon × Fairfax	297	1.3
Sparkle × Beacon	90	8.8
Crosses involving Cato:		
Cato × Fairfax	189	0.0
Crosses involving Catskill:		
Catskill × Royal Sovereign	114	0.0
Catskill × N. Y. 9270	79	0.0
Catskill × Clermont	21	0.0
Clermont × Catskill	115	0.9
Crosses involving Chesapeake:		
Chesapeake × Dresden	114	2.6
Chesapeake × Howard	254	1.5
Chesapeake × Royal Sovereign	348	0.0
Chesapeake × Clermont	83	0.0
Crosses involving Clermont:		
Clermont × Aberdeen	61	3.2
Clermont × N. J. 303	32	3.1
Clermont × Catskill	115	2.6
Clermont × Royal Sovereign	698	0.3
Clermont × Marshall	41	0.0
Clermont × Howard	31	0.0
Clermont × N. Y. 9270	29	0.0
Clermont × Oberschlesien	19	0.0
Fairfax × Clermont	26	3.8
Dresden × Clermont	132	1.5
Redheart × Clermont	96	0.0
Chesapeake × Clermont	83	0.0
Catskill × Clermont	21	0.0
Crosses involving Culver:		
Culver × Fairfax	18	0.0
Royal Sovereign × Culver	34	0.0
Redheart × Culver	24	0.0
Crosses involving Dorsett:		
Wyona × Dorsett	243	0.4
Dresden × Dorsett	78	0.0
Crosses involving Dresden:		
Dresden × Redheart	768	3.2
Dresden × N. Y. 6998	196	3.0
Dresden × Fairfax	970	2.8
Dresden × Sparkle	476	2.5
Dresden × N. J. 303	426	1.8
Dresden × Northstar	123	1.6
Dresden × Clermont	132	1.5
Dresden × Aberdeen	389	1.3
Dresden × Royal Sovereign	170	0.5
Dresden × Dorsett	78	0.0
N. J. 303 × Dresden	58	8.6
Sparkle × Dresden	365	4.9
Vanrouge × Dresden	298	4.0
Fairfax × Dresden	1050	3.0
Chesapeake × Dresden	114	2.6
N. Y. 7821 × Dresden	106	0.0
Aberdeen × Dresden	54	0.0
Redheart × Dresden	36	0.0
Crosses involving Fairfax:		
Fairfax × Clermont	26	3.8
Fairfax × Dresden	1050	3.0
Fairfax × Howard	203	1.4
Fairfax × Vanrouge	208	0.5
Wyona × Fairfax	162	9.8

TABLE I—(*continued*)

	Number Seedlings Grown	Percentage Selected
Aberdeen × Fairfax	108	4.6
Dresden × Fairfax	970	2.8
Howard × Fairfax	416	2.4
Beacon × Fairfax	297	1.3
Cato × Fairfax	189	0.0
Marshall × Fairfax	76	0.0
N. Y. 10501 × Fairfax	54	0.0
Culver × Fairfax	18	0.0
Crosses involving Howard:		
Howard × Fairfax	416	2.4
Howard × Royal Sovereign	21	0.0
Sparkle × Howard	371	5.3
N. Y. 6998 × Howard	105	3.8
Vanrouge × Howard	197	2.5
N. Y. 7225 × Howard	94	2.1
Chesapeake × Howard	254	1.5
Fairfax × Howard	203	1.4
Clermont × Howard	31	0.0
Crosses involving Marshall:		
Marshall × Fairfax	76	0.0
Marshall × Redheart	42	0.0
N. Y. 7225 × Marshall	53	0.0
Clermont × Marshall	41	0.0
Royal Sovereign × Marshall	29	0.0
Redheart × Marshall	24	0.0
Crosses involving Julymorn:		
Julymorn × Vanrouge	117	0.8
Sparkle × Julymorn	84	7.1
Crosses involving N. J. 303:		
N. J. 303 × Northstar	15	13.3
N. J. 303 × Dresden	58	8.6
Clermont × N. J. 303	32	0.8
Dresden × N. J. 303	426	1.8
Crosses involving Sparkle:		
Sparkle × Beacon	90	8.8
Sparkle × Julymorn	84	7.1
Sparkle × Howard	371	5.3
Sparkle × Dresden	365	4.9
Sparkle × Vanrouge	83	2.4
Dresden × Sparkle	476	2.5
Crosses involving N. Y. 6998:		
N. Y. 6998 × N. Y. 7225	110	7.2
N. Y. 6998 × Howard	105	3.8
Dresden × N. Y. 6998	196	3.0
N. Y. 7225 × N. Y. 6998	43	0.0
Crosses involving N. Y. 7225:		
N. Y. 7225 × Howard	94	2.1
N. Y. 7225 × Royal Sovereign	100	0.0
N. Y. 7225 × Marshall	53	0.0
N. Y. 6998 × N. Y. 7225	110	7.2
Crosses involving N. Y. 7821:		
N. Y. 7821 × Redheart	23	13.0
N. Y. 7821 × Dresden	106	0.0
U.S.D.A. 1021 × N. Y. 7821	97	5.1
Crosses involving N. Y. 9214:		
N. Y. 9214 × N. Y. 9565	71	0.0
N. Y. 9214 × Mastodon	36	0.0
Crosses involving N. Y. 9245:		
Royal Sovereign × N. Y. 9245	144	1.3
Paxton × N. Y. 9245	75	0.0
Crosses involving N. Y. 9270:		
Catskill × N. Y. 9270	79	0.0
Aberdeen × N. Y. 9270	30	0.0
Clermont × N. Y. 9270	29	0.0
Crosses involving N. Y. 10501:		
N. Y. 10501 × Fairfax	54	0.0

TABLE I—(*concluded*)

	Number Seedlings Grown	Percentage Selected
Crosses involving Northstar:		
N. J. 303 × Northstar	15	13.3
Dresden × Northstar	123	1.6
Crosses involving Paxton:		
Paxton × N. Y. 9245	75	0.0
Crosses involving Redheart:		
Redheart × Culver	204	0.0
Redheart × Clermont	96	0.0
Redheart × Dresden	36	0.0
Redheart × Corvallis	27	0.0
Redheart × Marshall	24	0.0
N. Y. 7821 × Redheart	23	13.0
Dresden × Redheart	768	3.2
Marshall × Redheart	42	0.0
Crosses involving Royal Sovereign:		
Royal Sovereign × N. Y. 9245	144	1.3
Royal Sovereign × Culver	34	0.0
Royal Sovereign × Marshall	29	0.0
Clermont × Royal Sovereign	698	0.3
Chesapeake × Royal Sovereign	348	0.0
Wyona × Royal Sovereign	211	0.0
Dresden × Royal Sovereign	170	0.0
Catskill × Royal Sovereign	114	0.0
N. Y. 7225 × Royal Sovereign	100	0.0
Howard × Royal Sovereign	21	0.0
Crosses involving U.S.D.A. 1021:		
U.S.D.A. 1021 × N. Y. 7821	97	5.1
Aberdeen × U.S.D.A. 1021	262	4.6
Crosses involving Vanrouge:		
Vanrouge × Dresden	298	4.0
Vanrouge × Howard	197	2.5
Sparkle × Vanrouge	83	2.4
Julymorn × Vanrouge	117	0.8
Fairfax × Vanrouge	208	0.5
Crosses involving Wyona:		
Wyona × Fairfax	162	9.8
Wyona × Dorsett	243	0.4
Wyona × Royal Sovereign	211	0.0

here. The few that were saved and those reported in a previous paper have nearly all been discarded.

Dresden has been used extensively in breeding because of its productiveness, freedom from nubbins, or malformed berries, and freedom from sterility of the flowers that bloom last on the cluster. In general, populations derived from Dresden are productive, but many of the seedlings are lacking in quality. The best selections came from crosses with Sparkle, Fairfax and Redheart.

The good showing of Beacon as a parent is probably due to the fact that it was crossed with Fairfax and Sparkle, both good parents. Beacon populations have many seedlings with large attractive berries and rather unproductive plants.

New York 6998 and 7225, both of which ripen several days earlier than Howard, were used to produce extra early seedlings, but most of the selections were not sufficiently productive to be of much value.

Aberdeen selections were made primarily to secure material for red stele resistance, but until tests have been made, not much can be said as to their ultimate value.

TABLE II—SUMMARY OF CROSSES INVOLVING EACH VARIETY

	Number of Crosses in Which Variety Appears	Number of Seedlings Grown	Percentage Selected
Aberdeen	6	904	2.7
Beacon	2	387	3.1
Cato	1	189	0.0
Catskill	4	329	0.9
Chesapeake	4	799	0.8
Clermont	13	1384	0.8
Culver	3	76	0.0
Dorsett	2	321	0.3
Dresden	18	5809	2.7
Fairfax	13	3777	2.6
Howard	9	1692	2.9
Julymorn	2	201	3.4
Marshall	6	265	0.0
N. J. 303	4	531	3.0
N. Y. 6998	4	454	3.9
N. Y. 7225	4	357	2.8
N. Y. 7821	3	326	2.7
N. Y. 9214	2	107	0.0
N. Y. 9245	2	219	0.9
N. Y. 9270	4	159	0.0
N. Y. 10501	1	54	0.0
Northstar	2	138	2.9
Paxton	1	75	0.0
Redheart	8	1220	2.4
Royal Sovereign	10	1869	0.2
Sparkle	6	1469	4.5
U.S.D.A. 1021	2	359	4.7
Vanrouge	5	903	2.3
Wyona	3	616	2.7

Parentage of unnamed varieties:
N. Y. 6998 Howard × Dutch Evern
N. Y. 7225 Howard × Dutch Evern
N Y. 7821 Howard × Marshall
N. Y. 9214 Howard × Mastodon
N. Y. 9245 Clermont × Schauber
N. Y. 9270 Clermont × Schauber
N. Y. 10501 Beacon × Howard
N. J. 303 N. J. 22 (Wyona × Aberdeen) × Fairfax

Redheart seedlings were usually unproductive and the berries rough and irregular with seedy tips. The chief value of Redheart as a parent would appear to be the production of varieties adapted to canning and freezing.

Chesapeake, in the combinations made, produced nothing of value. Marshall also failed to produce any seedlings of merit.

Royal Sovereign was crossed with 10 varieties and 1869 seedlings were produced, but only four were selected for further testing and these were soon discarded. The level of merit in all Royal Sovereign populations was very low. The results with this variety were disappointing in view of the success of Darrow in producing Dorsett and Fairfax from Royal Sovereign.

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The Influence of Certain Diseases and Threshing Injury on Stands of Flax and Peas in Washington

By Max L. Schuster, *Washington Agricultural Experiment Station, Pullman, Wash.*

MANY growers have complained of the failure to obtain good stands of flax and peas in Washington, even when seeds were planted under supposedly favorable conditions. Moreover, workers in the Agricultural Experiment Station at Pullman, Washington, in their varietal yield trials, noted that lots of seed of the same variety gave different emergence counts depending on the source of seed.

With these facts in mind, experiments were begun in 1941 to ascertain the cause of the difficulties involved. The problem of seed-borne diseases was given first consideration. Such diseases are damping-off and root rots of these crops. In this regard, isolations were obtained from the seed to determine what organisms were borne on the surface of the seed. Seed of six flax varieties and of canning and field varieties of peas were used in these determinations. Organisms isolated were a few bacterial types and many other fungi including Alternaria, Mucor, Rhizopus, and Penicillium. In order to determine whether these molds, which are usually not considered as parasitic, were responsible for poor stands obtained, further gross tests were made.

These experiments testing the pathogenicity of the isolates were accomplished by planting pea seed previously surface treated with chemical dusts and seed not sterilized into soil sterilized and not sterilized. From the sterilized soil there was no apparent difference in emergence of either treated or untreated seed. On the other hand, in unsterilized soil, surface treated seed gave a 20 per cent increase in stand over untreated seed. These results would indicate that seed-borne molds were of a minor consequence in causing poor stands. Therefore, work relative to seed-transmitted diseases was discontinued and soil-inhabiting fungi were given more consideration.

The soil-borne organisms were isolated from root and stem lesions on plants grown in the greenhouse and field. From the flax roots a *Fusarium* spp. was found to be consistently associated with the diseased areas. Similarly, *Rhizoctonia* and *Fusarium* spp. were obtained from pea roots. The flax isolate was tested in a preliminary manner and was found to be pathogenic. The pea organisms as yet were not run through pathogenicity tests though undoubtedly they are the chief causal agents because of their consistent association with diseased areas. Untreated seed sown in sterilized soil gave as good stands as treated seed, but not so in unsterilized soil. Beyond any doubt, soil-borne organisms played a major role in root and stem decay under the conditions of the experiments.

Another factor of importance in obtaining stands of flax and peas is injury to seed coats due to harvesting, threshing, and cleaning processes. Experiments have shown that lots of flax and peas differ in apparent susceptibility to damping-off organisms in direct relation to the percentage of cracked seed in the sample. The cracks give the seed- and soil-borne organisms ready access to the inside of the seed before the young seedling has an opportunity to become established. This injury is not merely confined to the seed coat but extends in many instances into the seed, causing damage to the embryo within. The cotyledon may be broken or the radicle may be injured so as to prevent proper germination as was found in our plating tests. This damage also may permit the loss of moisture and subsequent death of the embryo. Furthermore, certain molds are thus capable of causing damage to cracked seed in the soil whereas ordinarily they are unable to attack sound seed. Examples of such molds are Alternaria and Penicillium which are common soil saprophytes.

An examination of several lots of peas and flax revealed that they varied considerably in the percentage of cracked seed. Some lots of peas showed as many as two-thirds cracked seed. Of flax, the large-seeded varieties had the largest amount of cracked seed, reaching as high as one-half of the sample showing severe cracking. The smaller-seeded varieties showed cracking up to one-fifth of the sample drawn. Whether only size of seed is involved in this apparent correlation or whether varieties differ with respect to brittleness was not determined.

Further tests were run to determine the effect of seed coat injury on emergence. When two lots of the same flax variety, hand-threshed and machine-threshed, were planted in unsterilized soil in the greenhouse, some of the seed from the machine-threshed lot either failed to germinate or produced dwarfed seedlings thus causing a reduction in stand. The emergence of machine-threshed seed ranged from 20 per cent for the larger-seeded varieties to 50 per cent for the smaller-seeded varieties. The emergence of hand-threshed lots was almost perfect in some cases. Similarly, uncracked lots of pea seed gave an average emergence count of 80 per cent and the cracked seed lot gave about half this amount. These results would indicate that reduction in stand is probably directly related to the amount of seed cracking for it increased the susceptibility of seed to attacks by decay organisms.

Control measures were sought to offset the two factors, seedling diseases and threshing injury, that were responsible for poor stands of flax and peas in Washington. Since hand threshing as a partial means of control is impractical, another method had to be used. This was the use of seed treatment. The machine-threshed lots of flax were treated with fungicides such as Arasan, Spergon, and New Improved Ceresan. An average increase of 25 to 40 per cent in stand over the checks was obtained in greenhouse trials. Cracked pea seed lots on treatment with Spergon and Arasan showed an increase in stand of 12 to 23 per cent in field trials as shown in Table I.

As shown in Table I, treatment of uncracked seed also results in increased stands.

Our experiments have shown that it is important to plant undamaged seed, which is not always possible, and to have the seed treated with a fungicide. They also have shown that a part of the benefit derived from seed treatment is due to protection of cracked seed against invasion. Several seed treating dusts have been effective in increasing

TABLE I—EFFECT OF SEED TREATMENT ON INCREASING STANDS OF PEAS OF CRACKED AND UNCRACKED SEED LOTS IN FIELD TRIALS

Variety	Condition of Seed	Treatment (Dosage)	Emergence—Average Four Replications (Per Cent)
S537	Uncracked	Untreated	77.0
S537	Uncracked	Arasan (0.125%)	86.0
S537	Uncracked	Spergon (0.20%)	93.0
S537	Cracked	Untreated	41.0
S537	Cracked	Arasan (0.125%)	53.0
S537	Cracked	Spergon (0.20%)	64.0

flax and pea stands in Washington. In our trials it has been shown that the two main factors responsible for poor stands can be offset by the application of a chemical dressing to the seed.

The Effect of a Hydrophilic Colloid of High Viscosity on the Water Loss from Soils and Plants

By I. M. **Felber** and V. R. **Gardner**, *Michigan State College, East Lansing, Mich.*

ABSTRACT

This paper will be published in full as a Bulletin of the Michigan Agricultural Experiment Station, East Lansing, Michigan.

THE need of securing soil moisture to plants in areas of unfavorable climates, where water loss through evaporation from the soils and transpiration from the plants is extremely high without being balanced by sufficient precipitation, prompted the idea to conserve moisture by treating the soil with a hydrophilic colloid of chemical inertness.

In a series of experiments with potted bare soils and soils in which plants were growing, applications of methylcellulose[1] in a 1 or 2 per cent aqueous dispersion were made to the soil. The studies were carried out in the greenhouse and under controlled conditions of a chamber. They were conducted to determine: (1) The influence of methylcellulose on water loss from the soil and the plant, (2) its influence on the rate of plant growth and on water requirement.

Equal amounts of air-dry soil (greenhouse compost, sandy soil or sand) were put into stoppered clay-pots or tin cans and the desired soil moisture was adjusted by adding water to the controls and the same amount of Methocel sol to the other containers. This sol was either mixed with the whole volume of soil or applied on its surface. The initial weights of the adjusted pots were recorded, as were afterwards the amounts of daily water losses.

The plant materials were seedlings or cuttings (such as beans, tomatoes, Jerusalem cherry, Coleus, Tradescantia) which were transplanted into the treated and non-treated soil. In other cases treatments were given after the plants had become well established in a definite soil volume and their water losses had been determined during a period of time, while other pot-grown plants were left as controls. Exact amounts of water lost through evaporation or evaporation and transpiration were obtained for each individual pot by daily weighings within groups of five or ten replications.

The results of the experiments indicate that evaporation losses from bare soils and potted plants can be greatly reduced (about 30 to 50 per cent) by applying an aqueous dispersion of methylcellulose to the soil. Repeated treatments had an accumulative effect on the reduction of water loss. The effectiveness of initial treatments in retaining moisture against the evaporating force remained unaltered over more than 3 months. No plants have been harmfully affected by methylcellulose. In sand and sandy soil growth was remarkably benefitted and accelerated. Under drying conditions methylcellulose restricted the water loss so appreciably that soil moisture was still available to plants, while it was exhausted in the controls. Consequently, wilting was delayed by several days.

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[1] The methylcellulose used in this study is a product of The Dow Chemical Company, Midland, Michigan, and is sold under the trade name of "Methocel".

In culture solution methylcellulose effected a reduction of the water requirement of corn and bean plants, amounting to about 30 per cent, during 1 month of growth. This effect resulted either from less water absorption, from an increase in growth, or from both factors simultaneously.

It is assumed, on the basis of the results obtained from this study, that methylcellulose, or other similar hydrophilic colloids, may have far reaching importance in agricultural and horticultural practice. Its application may help to overcome temporary drought periods, to reduce labor and expenditure of artificial irrigation, and to control erosion and runoff from sandy soils.

Tests With Newer Lettuce Strains[1]

By G. J. RALEIGH, J. F. HARRINGTON, R. KUNKEL, and
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IT WAS recognized by Knott, Anderson, and Sweet (1) that Imperial 44, although the most satisfactory strain of lettuce of the Iceberg type for production on New York muck soils then available, was not as resistant to tipburn as desired. Work was continued to select a strain with greater tipburn resistance and ability to form hard heads in warm weather. Of the many strains obtained from the United States Department of Agriculture and from other sources, a cross of Brittle Ice and Imperial 152 (U.S.D.A. 8355M) contained plants of superior quality as far as tipburn resistance and firm heading were concerned. Many selections from that strain were made as well as from crosses made by Knott between Imperial 44 and Brittle Ice, between selections from 8355M and Imperial 44, and between many other strains of the Iceberg type that had showed some desirable qualities in the earlier work. Among the selections were a few made from U.S.D.A. 10899M which had been selected from 8355M.

In 1940 three strains, two of which were selections from 8355M and one from 10899M, were chosen from the large number of strains tested that year. Seed of the three was increased for larger trials in 1941.

In 1941 the selection from 10899M was chosen as the best of the three and was introduced in cooperation with the United States Department of Agriculture as 456.

After 1941 nearly all strains not of Brittle Ice parentage were discarded as inferior and efforts were made to eliminate one of the most objectionable features of 456, a tendency to form ribby heads.

To date these efforts have not been successful. In general, when strains such as 456 were backcrossed to Imperials susceptibility to tipburn increased. Great Lakes (2), a promising strain recently introduced jointly by Michigan State College and the United States Department of Agriculture, is of that general parentage. In our trials it too has shown more tipburn than 456. Both are much more dependable for summer lettuce production in New York than is Imperial 44. During 1943 and the preceding three years, Imperial 44 has not been marketable in any trial, maturing in late July or early August. In only one case has 456 failed to produce a marketable crop — in 1943 one planting was a complete failure due to aster yellows. That disease has caused severe losses in three of the last four years. It was particularly destructive in early August, 1943. In trials to date there has been no evidence that any strain tested showed any resistance to it.

It should be kept in mind that 456 was selected for New York State muck soils which produce quick growth and large size plants. To obtain good production on upland soils, observations indicate that 456 should be well fertilized and grown on soils that may be irrigated.

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[1] Paper No. 257, Department of Vegetable Crops, Cornell University, Ithaca, New York.

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An Improvement in Bean Crossing Technique

By B. L. WADE, *U. S. Regional Vegetable Breeding Laboratory, Charleston, S. C.*

DURING several years work with beans it has been found that crossing is one of the most difficult and uncertain operations involved. Other investigators have also encountered difficulties with Phaseolus crosses, namely, Tschermak (4), Emerson (1), Kooiman (2), and Strand (3). Since the making of artificial crosses under field conditions usually has not been satisfactory, most crosses made at the Regional Vegetable Breeding Laboratory at the present time are with plants grown under greenhouse conditions. Results are not always satisfactory even in the greenhouse, but with thrifty plants held in high atmospheric humidity it is usually possible to count on 10 to 20 per cent of the artificially pollinated flowers setting pods.

Attempts have been made to improve the set of pods, but only during the winter of 1942–43 were these attempts successful. Although an abundance of flowers were available never more than 20 crosses were made in any one day in order to conduct the tests under a range of conditions over a period of several days. The new techniques and the check procedure were alternated with every cross so as to avoid giving one method an apparent advantage over another.

The following procedure, commonly used here in the past, was employed as a check on the new techniques: A plump bud is selected, held gently between the thumb and forefinger of the left hand while the keel is peeled open carefully with a pair of sharp-pointed tweezers in the right hand. If removal of any portion of the keel petals results in any severe strain on the style or if any crack or break develops in the style, that flower is discarded. The stamens are counted and removed carefully. Pollination is accomplished by scraping the pollen from the stigma of a flower intended for the male parent by means of the tweezers and transferring it promptly to the stigma of the flower intended for the female parent. After the transfer, the stigma is covered as completely as possible with the remaining petals in order to conserve moisture.

The new techniques were exactly the same as the check procedure except that in technique A the banner of the flower used as the male parent was crushed in the mouth of the operator and placed immediately following transfer of pollen over the injured floral surface of the flower used for the female parent; and in technique B the banner was crushed between the fingers under water and transferred as in A. With method A, 21 out of 40 pollinated flowers set pods, while with B, 18 out of 40 set pods. The check set 14 pods from 80 flowers. On a percentage basis, this is an average of 48.75 per cent set for the "crushed banner" techniques in comparison with 17.50 per cent for the check.

The improved method has been used in connection with two greenhouse crops and appears to be of promise. Some work in which pieces of Petunia petals were used gave results comparable to those obtained with bean blossom petals. When the crushed banner dries it adheres tightly to the emasculated flower probably forming a small damp chamber fairly comparable to that found in a normal flower with unbroken keel. As the young pod develops it pushes off the floral parts in a manner normal for a pod from an unmolested flower.

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Inheritance of Male Sterility in the Onion and the Production of Hybrid Seed

By HENRY A. JONES and ALFRED E. CLARKE, *U. S. Department of Agriculture, Beltsville, Md.*

THE utilization of hybrid vigor in plants had its inception and greatest stimulus in the production of hybrid corn. The use of hybrid seed to increase yields of squash, tomatoes, and muskmelons has been advocated by a number of investigators. Jones and Emsweller (7) suggested that hybrid onion seed might be produced on a commercial scale by using a male-sterile onion found in the variety Italian Red as the female parent. A knowledge of the genetics of the male-sterile character is desirable in order to determine the best breeding procedure for developing male-sterile lines. This paper describes the mode of inheritance of male sterility in the onion, which has been found to be partly cytoplasmic and partly nuclear in nature, and also discusses the manner in which this character may be utilized in a breeding program.

REVIEW OF LITERATURE

Male sterility may result from any one of several causes, including unfavorable environmental conditions, chromosomal irregularities during meiosis, or the presence of Mendelian genes for sterility. In a male-sterile line of maize Rhoades (10, 11) showed that the pollen sterility was inherited through the maternal cytoplasm.

East (4) found that certain *S* factors from *Nicotiana sanderae* produced male sterility in the presence of cytoplasm derived from *N. langsdorfii* but produced viable pollen in the presence of *N. sanderae* cytoplasm.

In a cross between procumbent and tall flax Bateson and Gairdner (1) obtained the ratio 3 normal: 1 male-sterile in the F_2 generation. Male-steriles were obtained only when a plant of the procumbent strain was pollinated by a tall plant, not when a tall was pollinated by a procumbent. Later Chittenden and Pellew (3) and Chittenden (2) explained these results as the interaction of a Mendelian recessive in the cytoplasm of the procumbent strain.

Owen (9), working with the sugar beet, found that several pairs of Mendelian factors may influence pollen development when carried by plants with sterile cytoplasm, but the same factors have no effect when carried by plants with normal cytoplasm.

Jones and Davis (5) have found that by combining suitable inbred lines it is possible to obtain very productive onion hybrids. Consequently, if the seed could be produced at reasonable cost the utilization of these hybrids should be practicable on a commercial scale.

The male-sterile onion described by Jones and Emsweller (7) produced bulbils and has been perpetuated as a clonal line under the number 13–53. Monosmith (8) found no irregularities in chromosome behavior of 13–53 during the reduction divisions, but later the microspores degenerated, so that no viable pollen was produced.

MATERIALS AND METHODS

To obtain data on the inheritance of male sterility crosses were made between the male-sterile line 13–53 and a large number of commercial varieties. While these male-sterile plants produce no viable pollen they set seed readily when hybridized with pollen from normal male-fertile plants.

To facilitate crossing flies were used as pollinating agents, as described by Jones and Emsweller (6). Data were obtained from F_1, F_2, F_3, first and second generation backcross populations grown in the greenhouses at the Bureau of Plant Industry Station, Beltsville, Maryland.

EXPERIMENTAL RESULTS

When male-sterile plants of the line 13–53 were crossed with various male-fertile plants, three types of breeding behavior were observed in the F_1, some progenies being entirely male-fertile, others entirely male-sterile, whereas still others produced both male-sterile and male-fertile plants in a 1 : 1 ratio (Table I).

TABLE I—INHERITANCE OF MALE STERILITY IN CROSSES BETWEEN MALE-STERILE AND NORMAL LINES OF ONIONS

Parent or Cross	Generation	Parental Genotypes	Expected Ratio		Number Plants Obtained		Deviation/ Standard Error
			Male-Sterile	Male-Fertile	Male-Fertile	Male-Sterile	
Male-sterile 13-53 ×male-fertile	F_1	*S ms ms* × *N Ms Ms*	1	0	62	0	—
Male-sterile 13-53 ×male-fertile . . .	F_1	*S ms ms* × *N ms ms*	0	1	0	225	—
Male-sterile 13-53 ×male-fertile.. . ..	F_1	*S ms ms* × *N Ms ms*	1	1	98	86	Less than 1
F_1 male-fertile	F_2	*S Ms ms* selfed	3	1	375	155	2.3
F_2 male-fertile ..	F_3	*S Ms ms* selfed	3	1	96	41	1.3
Male-sterile 13-53 ×F_1 male-fertile.	Backcross selfed	*S Ms ms* selfed	3	1	98	49	2.4
F_1 male-sterile ×male-fertile	Backcross selfed	*S Ms ms* selfed	3	1	104	24	1.6
F_1 male-sterile ×male-fertile	Backcross	*S ms ms* × *N Ms Ms*	1	0	20	0	—
F_1 male-sterile ×male-fertile	Backcross	*S ms ms* × *N ms ms*	0	1	0	458	—
F_1 male-sterile ×male-fertile	Backcross	*S ms ms* × *N Ms ms*	1	1	157	163	0.3
Male-sterile 13-53 ×F_1 male-fertile ..	Backcross	*S ms ms* × *S Ms ms*	1	1	200	246	2.2
F_1 male-fertile ×male-fertile	Backcross	*S Ms ms* × *N ms ms*	1	1	33	32	Less than 1
Male-fertile ×F_1 male-fertile	Backcross	*N ms ms* × *S Ms ms*	1	0	53	0	—
Male-sterile ×male-fertile..	Second backcross	*S ms ms* × *N ms ms*	0	1	0	275	—
Male-sterile ×male-fertile .	Second backcross	*S ms ms* × *N Ms ms*	1	1	125	142	1.0

When a self-fertile F_1 plant is selfed, the F_2 approximates the ratio 3 normal : 1 male-sterile. The total for all of the F_2 populations is shown in Table I. It will be noted that the fit to a 3 : 1 ratio is rather poor, the deviation being 2.3 times the standard error. An examination of the table will show that there is a slight excess of male-steriles in almost every case where the populations are assumed to be segregating for 3 : 1 or 1 : 1 ratios. Since high temperatures in the greenhouse during the flowering period reduced the percentage of viable pollen produced by male-fertile plants, it is probable that occasionally a heterozygous plant, while genotypically male-fertile, was classified as male-sterile.

Segregating F_3 and selfed backcross populations were also found to approximate 3:1 ratios.

When a male-sterile F_1 is backcrossed to the male-fertile parent three types of segregation are obtained, as in the F_1 (Table I). When the 13–53 male-sterile parent is backcrossed with an F_1 male-fertile plant, a 1:1 segregation is obtained.

In crosses between certain F_1 male-fertile plants used as the female parent and the male-fertile parent line a ratio of 1 male-fertile to 1 male-sterile is obtained. But in the reciprocal backcross, when the F_1 male-fertile plant is used as the pollen parent, all of the progeny are male-fertile (Table I).

Some second backcrosses gave a 1:1 segregation; other second backcrosses gave all male-steriles (Table I).

DISCUSSION

EXPLANATION OF EXPERIMENTAL RESULTS

These results may be accounted for by assuming that the male-sterile condition results from an interaction between a recessive nuclear gene and a non-nuclear or cytoplasmic factor. On this hypothesis it is assumed that there are two types of cytoplasm. All plants with normal cytoplasm (designated for convenience as N) produce viable pollen. All male-sterile plants possess the sterile type of cytoplasm (*S*). The experimental results throw no light on the nature of the non-nuclear or cytoplasmic factor which differs in the two types. A gene for male sterility (*ms*) also influences pollen development when carried by plants with *S* cytoplasm but has no effect when carried by plants with *N* cytoplasm. Consequently, the 13–53 male-sterile plants belong to the genotype *S ms ms*. Plants with *N* cytoplasm are male-fertile always and may belong to the genotypes *N Ms Ms, N Ms ms,* or *N ms ms*, since the ms gene has no effect in the *N* cytoplasm. Apparently there is no natural selection for or against the recessive ms gene, when it is present in *N* cytoplasm. Plants with the genetic constitution *S Ms Ms* and *S Ms ms* will also be male-fertile, in spite of the *S* cytoplasm, because they carry the dominant gene *Ms*.

The non-nuclear or cytoplasmic factor is inherited only through the egg (maternal transmission) and not through the male parent, presumably owing to the very small amount of cytoplasm present in the male gamete. From the cross *S ms ms* x *N Ms Ms* all F_1 plants will be *S Ms ms* and, in spite of the *S* cytoplasm, are male-fertile because they carry the gene *Ms*. *S ms ms* x *N ms ms* gives all male-sterile, and *S ms ms* x *N Ms ms* gives 1 male-sterile: 1 male-fertile. When a self-fertile F_1 plant (*S Ms ms*) is selfed, the expected F_2 ratio is 3 normal: 1 male-sterile.

All male-sterile F_1 plants belong to the genotype *S ms ms*. *S ms ms* x *N Ms Ms* produces all male-fertile. *S ms ms* x *N ms ms* produces all male-sterile and *S ms ms* x *N Ms ms* produces 1 male-fertile: 1 male-sterile. When the 13–53 male-sterile parent is backcrossed with an F_1 male-fertile plant, *S ms ms* x *S Ms ms*, a 1:1 segregation is expected.

When an F_1 male-fertile plant, *S Ms ms,* is used as the female parent and backcrossed to *N ms ms* a ratio of 1 male-fertile to 1 male-sterile is obtained. But in the reciprocal backcross *N ms ms* x *S Ms ms* all of the progeny are male-fertile, since all carry *N* cytoplasm. The unlike behavior of these reciprocal backcrosses is additional evidence in support of the validity of this hypothesis.

Second backcrosses of the type *S ms ms* x *N Ms ms* gave a 1:1 segregation. Second backcrosses of the type *S ms ms* x *N ms ms* gave all male steriles. This confirms the expectation that 100 per cent male-sterile progenies can be obtained in repeated backcrosses to a stock with the genetic constitution *N ms ms.* As will be shown later this is of great practical importance in developing a breeding program.

Application of Genetic Results to a Breeding Program

The production of hybrid onion seed of all types and in quantity is now possible. To perpetuate the pure male-sterile line two lines must be carried along: a male-sterile line of the genotype S ms ms and a fertile line of the genotype N ms ms. All of the progeny of this cross will be male-sterile. Fig. 1 illustrates the method of perpetuating the male-sterile line through the seed.

As the male-sterile plants cannot be selfed, seed is secured by continually backcrossing to the normal or male-fertile line. Backcrossing continues as long as the particular male-sterile line is to be perpetuated. After a few backcrossings the male-sterile line should be practically identical with the male-fertile except for the sterility factor of the cytoplasm. This backcross seed makes it possible to perpetuate the male-sterile line, as well as produce the male-sterile female parents used in the production of hybrid seed.

The next step is to make crosses between the male-sterile line and other selected lines to determine which combination produces the best commercial hybrid (Fig. 2). The constitution of the male parent that enters into the cross for the production of commercial hybrid seed may be *N ms ms, N Ms ms,* or *N Ms Ms,* the particular one selected being based on progeny tests. The behavior of the commercial hybrids as to fertility is not important, because the commercial crop must be grown from hybrid seed each year. It is important, however, to get a favorable combination of growth factors.

As stated above, the cytoplasmic factor for male sterility (S) was found in the Italian Red 13–53 variety. No doubt this character may also be present in other varieties. The genotype *N ms ms* that produces all male-sterile plants when crossed with *S ms ms* has been found in Brigham Yellow Globe, Early Yellow Globe, Sweet Spanish, Southport White Globe, Crystal Wax, Creole, and Stockton G 36, so it is possible to get male-sterile cytoplasm into these varieties by continuous backcrossing. As many as three backcrosses have been made to a number of them. Male-sterile lines could be produced in an $N\ Ms\ Ms$ variety by alternating backcrossing and selfing.

The best method of interplanting male-sterile and male-fertile lines in the field to secure the highest return of hybrid seed has not been worked out as yet.

The type of breeding program just outlined should be applicable to any crop plant in which male sterility is inherited in this way, provided that the plant, like the onion, is naturally cross-pollinated and displays hybrid vigor in the F_1.

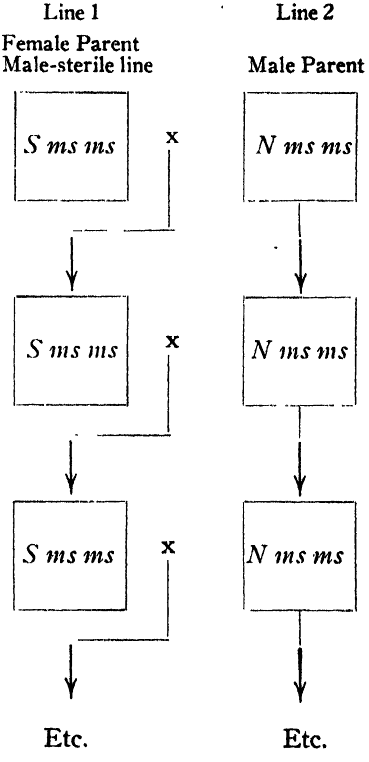

FIG. 1. Method of perpetuating the male-sterile lines.

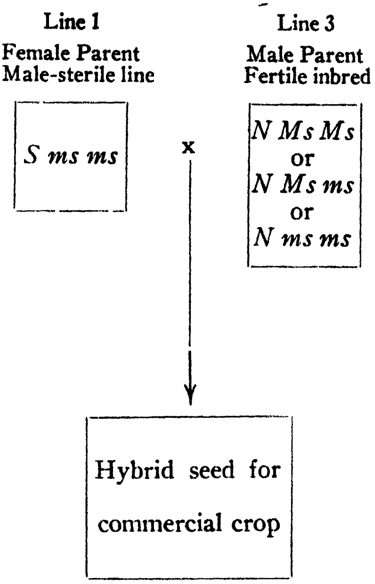

FIG. 2. Method of perpetuating hybrid seed for the commercial crop.

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A Source of Muskmelon Mosaic Resistance Found in the Oriental Pickling Melon, Cucumis melo Var. Conomon

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MOSAIC on the muskmelon, *Cucumis melo* var. *reticulatus,* caused chiefly by cucumber virus No. 1 and the ordinary muskmelon virus is a limiting factor in the production of this crop in New York State. It became so troublesome in the breeding grounds on the Station farms and in the surrounding territory that the original objectives of the melon breeding program had to be adjusted to include mosaic resistance as a prerequisite to further progress.

In the spring of 1941 a systematic search was initiated to discover a source of natural resistance to mosaic causing injury on muskmelons. The following materials were used in the experiment: *Cucumis melo* var. *reticulatus,* 10 lots; *C. melo* var. *flexuosus,* one lot; *C. melo* var. *Dudaim,* one lot; *C. melo* var. *Chito,* two lots; *C. melo* var. *Conomon,* four lots; and material from the Division of Foreign Plant Introduction, secured from India, Turkey, Afghanistan, Brazil, Paraguay, and Argentina, 84 lots. Most of these were varieties either of *C. melo* var. *cantalupensis* or of *C. melo* var. *inodorus.*

METHODS

Most of the seed was quite old and the germination weak when this experiment was undertaken. In order to obtain seedlings all lots were pre-germinated between blotters. These were transferred to 2½-inch clay pots and when the seedlings had attained the cotyledon stage 20 plants were selected for the tests. Five of them were inoculated on the upper surface of both cotyledons with cucumber virus No. 1, five with melon mosaic virus, five with both viruses, the cucumber virus on one cotyledon and the muskmelon virus on the other, and five were left as checks.

The inoculum for both viruses was secured from diseased melon plants provided through the courtesy of Dr. Munger of the Department of Plant Breeding, Cornell University, Ithaca, New York. The juices freshly expressed from the diseased leaves by a hydraulic press were applied to the upper surface of the cotyledons with small glass stirring rods having one end bent to a 30 degree angle and the under side ground to a rough surface for its abrasive action.

The plants were grown for 3 weeks during which period they were given two applications of a complete nutrient solution in order to maintain as normal growth as possible in their small containers. At the expiration of 3 weeks all plants showing mosaic symptoms were discarded and the remainder, including apparently resistant plants, possible escapes and checks, were transplanted to a farm 8 miles from Geneva where the commercial production of muskmelons had become impossible due to the severity of mosaic. At this stage 80 per cent of the material had been discarded.

The transplanted melons were grown in accordance with the accepted commercial methods of the area. Except for an initial dusting to protect the succulent plants from severe insect damage, no subsequent precautions were taken to control the natural insect vectors thought to be responsible for disseminating the virus from the native host plants.

RESULTS FROM THE 1941 TEST

The final observations were recorded August 6, 1941. At that time all varieties of *Cucumis melo* var. *reticualtus,* all plants grown from the Foreign Plant Introduction seed and the plants from all but one of the botanical varieties of *C. melo* showed typical mosaic symptoms of either or both viruses. Two horticultural varieties of *C. melo* var. *Conomon,* Freeman Cucumber and White Melon, failed to exhibit mosaic symptoms on any of the plants. One other variety, Gin-makuwa or Kin-makuwa as it is sometimes listed, showed considerable resistance although several plants developed slight symptoms of both mosaic viruses.

1942 TESTS

In the early spring of 1942 crosses were made in the Station greenhouses between several experimental varieties of *Cucumis melo* var. *reticulatus* and the three horticultural varieties of *C. melo* var. *Conomon* found in 1941 to have considerable mosaic resistance. The F^1 seeds from these hybrids developed in time to grow the F^1 plants from them in the field the same season. In most crosses the embryonic development of the F^1 seeds was abnormally small. It was found necessary to excise the embryos and to germinate them as naked embryos at room temperatures in petri dishes equipped with absorbent cotton pads moistened with a dilute (1 per cent) solution of KNO_3. The viable seedlings were then transferred to 2½-inch clay pots and grown in the manner previously described.

Three inoculations were made on all F^1 seedlings used in the experiment. Since the cucumber mosaic virus No. 1 was the most lethal in its effect on the crop, the 1942 tests were limited to this virus. They were first inoculated at the cotyledon stage in the manner described above just as the first true leaf began to emerge. The inoculum was the freshly expressed juice of a melon plant having typical and pronounced symptoms of the mosaic in question. When no symptoms of mosaic developed on any plant after 2 weeks, a second inoculation was given. This was accomplished by piercing the first and second true leaves with the bristles of a small circular steel brush the points of which were dipped in freshly expressed inoculum.

One week later on July 3, 1941 after symptoms of mosaic failed to appear a representative sample from each of nine F^1 progeny lines was transplanted in the field to determine if natural insect vectors would transmit the disease. No evidence of mosaic was found on any plant for 3 weeks and on July 25, 1942 the third inoculation was given. This was made by injecting the inoculum with the aforementioned steel brush into the growing runners about 6 inches from the tips and over an area of 3 or 4 inches. This in effect appeared to simulate the injury commonly caused by the cucumber beetle, although it was thought that the striped cucumber beetle seemed to feed much less on the hybrid plants than on the varieties of *Cucumis melo* var. *reticulatus.*

RESULTS FROM THE 1942 TESTS

The first evidence of mosaic was discovered about 2 weeks after the third inoculation. Subsequent observations were made August 24 and September 10. The symptoms on the susceptible plants ranged from very slight to moderate mottling. Whereas the varieties of *Cucumis melo* var. *reticulatus* grown as checks were practically ruined, no severe injury was found on any plant in any F^1 progeny line of the hybrids. In Table I are data obtained from these tests. The size of the populations was probably too small to secure an accurate analysis of the inheritance.

TABLE I—PERFORMANCE OF THE F^1 GENERATION FOR RESISTANCE TO CUCUMBER VIRUS 1 IN NINE CROSSES BETWEEN *Cucumis melo Conomon* AND *C. melo reticulatus*

F^1 Hybrid No.	Parentage*	Plants Apparently Free		Susceptible in Varying Degrees		Total Population
		Number	Per Cent	Number	Per Cent	
124	K-2 × Aristogold 43–44	6	100	0	0	6
125	FC-2 × Aristogold 43–5	2	67	1	33	3
126	K-1 × Mardela 3–23	23	82	5	18	28
128	K-3 × FR-13–6	12	67	6	33	18
129	FC-3 × FR-13-7	6	32	13	68	19
130	FC-2 × Mardela 46–7	2	15	11	85	13
132	Aristogold 43-13 × K-2	16	46	19	54	35
135	Mardela 7–55 × FC-3	14	100	0	0	14
136	Aristogold 43–47 × FC-3	15	100	0	0	15
	Totals	96	64	55	36	151

*Lines K-1, K-2, K-3, FC-2 and FC-3 are selections from two varieties of *Cucumis melo Conomon;* all other lines are selections of *C. melo reticulatus.*

Unfortunately two of the three horticultural varieties of *Cucumis melo* var. *Conomon,* Freeman Cucumber and White Melon, have definitely inferior quality in comparison to that of the true muskmelon. The other one, Gin-makuwa or Kin-makuwa, possesses fairly good quality. A brief description of each follows.

Freeman Cucumber:—Plants moderately vigorous, medium green foliage. *Leaves* similar in shape to those of *Cucumis melo* var. *reticulatus* although the margins are more deeply serrated and undulating. *Vines* moderately spiny, intermediate between those of *C. melo* var. *reticulatus* and those of Gin-makuwa. *Flowers* usually andromonoecious with complete flowers borne on long, vigorous fruiting branches; staminate flowers few in number, the first ones usually borne singly, later produced in clusters with periodic blooming cycle. *Fruits* oblong oval, 7 to 8 inches long and 3½ to 4½ inches in diameter; bright yellow skin color; surface smooth, without ribs or netting. *Flesh* nearly white, firm fine texture, ¾ to 1 inch thick; insipid and lacking sweetness. Early maturity. Source of seed — Lank Brothers, Wichita, Kansas.

White Melon:—This is similar in type to Freeman Cucumber, although the plants are more vigorous, and the fruits are larger and more creamy yellow in skin color. The fruits average 10 to 12 inches long and 4 to 6 inches in diameter. Late maturity. Source of seed — Oriental Seeds and Plants, 1707 Geary Street, San Francisco, California.

Gin-makuwa or *Kin-makuwa:*—Plants medium to moderately weak vigor. *Leaves* dark green and are more distinctly lobed than those of *Cucumis melo reticulatus* varieties. *Vines* very spiny, closely approaches that of *C. sativus* varieties. *Flowers* both dioecious and andromonoecious with pistillate or complete blossoms borne on very short fruiting stalks at base of leaves on short fruiting branches; frequently leaves partially envelope blossom stalks; staminate flowers at each leaf axil, distinctly fewer in number than on varieties of *C. melo* var. *reticulatus*. *Fruits* globular to short oval, 3 to 3½ by 2¾ to 3 inches in size, weight 1 to 1½ pounds; skin color cream with yellow blotches and very narrow green streaks at sutures; surface smooth, without ribs or netting. *Flesh* greenish white, ⅝ to ¾ inch thick, sweet, delicately aromatic, not musky. Early maturity. Source of seed — Oriental Seed and Plant Company, San Francisco, California.

This paper is presented as a preliminary report on this phase of melon breeding. Since there is apparently no published record of *Cucumis melo* material having resistance to mosaic, it is suggested that among the horticultural varieties of *C. melo* var. *Conomon*, both those here described and possibly other similar but little known sorts, may be found material for further study in the development of mosaic resistant muskmelons.

The Characteristics of Crosses Between Botanical Varieties of Cabbage, Brassica Oleraceae

By A. F. Yeager, *New Hampshire Agricultural Experiment Station, Durham, N. H.*

PROBABLY no species of plants has undergone so much change in domestication as cabbage. Commonly grown variations within this species include cabbage, Brussels sprouts, cauliflower, green sprouting broccoli, kohlrabi, and kale. As a student project at the University of New Hampshire, all these variants were brought into bloom in the greenhouse in 1941. As practice in plant breeding, crosses were made between them. The resulting seed matured before planting time in the spring of 1942 was sown inside, and transplanted to the field about the middle of May.

Since many of the combinations had not previously been observed by the writer, it was thought desirable to make a record of their characteristics for the benefit of others who might be interested. The descriptions which follow were made by combining notes taken several times throughout the growing season, the final one late in October. While reciprocal crosses were made and plants grown, separate descriptions are not given since they were practically identical in every case. Possibly the characteristics of these plants may suggest to some plant breeder other variants of cabbage which might be produced, purified, and introduced as a new vegetable.

The references at the close of this article (1, 2, 3) give considerable data on the inheritance of various characteristics in the Brassica genus. For the most part major characters seem to be the result of several genes in each case. This would need to be taken into consideration in any breeding program.

Kohlrabi x Broccoli:—The final result was a very heavy elongated swollen stem with side branches varying from 2 inches in length with a bulbous form, up to flowering stalks 3 feet in length. A few of the terminals showed slight broccoli heading tendencies.

Kohlrabi x Brussels Sprouts:—The plants had fairly clean, much enlarged stalks up to 10 inches in length, some with few branches, generally with numerous short, small branches 1 inch in length. These plants resembled Kohlrabi to a considerable extent.

Kohlrabi x Cabbage:—Gave a rather coarse kohlrabi-like stem with many thickened side branches from 1 to 3 inches in length, some of which carried practically no leaves but had well-developed leafy terminal buds.

Kohlrabi x Cauliflower:—Resulted in a coarse, heavy stem with leafy branches some 6 inches in length terminated by imperfect heads which resembled poor leafy cauliflower.

Kohlrabi x Kale:—Produced a heavy stem resembling elongated kohlrabi but with many side branches 2 to 3 inches in length which were somewhat swollen. Leaves kale-like but with shorter petioles. The general appearance of the plant was that of a short kale plant.

Brussels Sprouts x Broccoli:—Plant resembled Brussels sprouts except that the sprouts were poorly developed. At the top there was a tendency to branch. Some of the branches were several feet long by autumn and bore blossoms and undeveloped seeds.

Brussels Sprouts x Cabbage:—A much elongated, fair sized, pear shaped head was produced at the top, with rather loose sprouts in the axils of the leaves farther down on the stalk.

Brussels Sprouts x Cauliflower:—The plants resembled Brussels sprouts with 12 inch stalks, but these produced no axillary heads. Near the top several 4 inch leafy branches were produced. There was no cauliflower head.

Brussels Sprouts x Kale:—Superficially looked like a tall kale. A close examination showed leafy sprouts all the way up the stalk, some of which were several inches in length.

Cauliflower x Green Sprouting Broccoli:—Developed into a branchy plant with the branches 1 foot in length. Resembled green sprouting broccoli to a considerable extent. The heads were very leafy and light green and not as well developed as either broccoli or cauliflower.

Cauliflower x Cabbage:—Good-sized long, slender heads with a heavy core. This breaks into 10 to 20 small elongated, heads later in the season by rupturing the outer enclosing leaves.

Cauliflower x Kale:—About 8 inch stalk bearing kale-like leaves. At the top of plant many branches 3 or 4 inches in length, some of which showed small cauliflower-like heads. General appearance of the plant kale-like.

Cabbage x Green Sprouting Broccoli: — These produced well-developed flowerstalks 2 feet in length with many flower shoots. Several axillary branches near the ground. Terminals neither cabbage head nor broccoli though some resemble broccoli about 1 inch in diameter in their early stages and one plant bloomed.

Cabbage x Kale:—The general appearance was that of a short-stemmed, quite leafy, attractive kale. No head produced.

Kale x Broccoli:—The plant looked much like a branchy kale, a few of the terminals of which carried poorly developed small broccoli-like heads. About half the plants bloomed before winter.

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The Trend of Starch Reserves in Bean Plants Before and After Irrigation of a Saline Soil

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AS THE moisture content of a saline soil decreases, there occurs a corresponding increase in the concentration of the soil solution. Under such a condition, the concentration of the soil solution may reach a point where inhibition to plant growth is involved (12, 13). Most evidence from studies in artificial substrates indicates that this inhibitive effect is brought about through osmotic forces rather than by toxicity of specific ions (3, 5, 6, 12). In addition to the concentration effect of the soil solution during soil desiccation, the tension with which water is held in the soil mass increases, approaching about 15 atmospheres at the wilting percentage (15). In other words, two distinct physical forces appear to be operative in the retention of water from plants' roots: (a) osmotic pressure of the solution, and (b) "capillary" forces of the soil particles. Even though the "capillary" force is approximately 15 atmospheres at the permanent wilting percentage, many investigators (8, 19, 20) find that all soil moisture above this percentage is equally available to plants. Others (1, 2, 4, 9, 11) have challenged this view, although mainly on theoretical grounds. The relative effect of osmotic forces vs. "capillary" forces on the availability of water to plants is still a point of contention; yet, it is a very pertinent consideration with crops on saline soils which are allowed to dry out considerably before being irrigated.

In view of the increase in concentration of the soil solution as an irrigated saline soil dries toward the wilting percentage, it seemed that definite modifications in plant response would be concurrently observable. The level of starch reserves was regarded as being a possible index of the induced changes, since Spoehr and Milner (18) had shown that water stresses within the plant bring about increased amylolytic activity and dissolution of starch reserves. Accordingly, an experiment designed to test this view was carried out with Red Kidney bean plants grown in 10-gallon steel drums containing 100 pounds (dry) of Fallbrook loam soil. This soil is non-saline and low in fertility. Its permanent wilting percentage as determined with sunflower plants was 6.1 per cent, its moisture equivalent was 14.7 per cent, and its normal moisture-holding capacity 18.0 per cent. The saturated soil paste had a pH of 7.8 and a conductance of 34.2×10^5 at 25 degrees C. The drums were filled with this soil in a manner previously described (1); half of the containers received soil to which no salt (other than fertilizer) had been added, and the other half were filled with soil containing 0.2 per cent sodium chloride (dry soil basis). Each drum received 23 gms of a 6–8–6 fertilizer, equivalent to a rate of 1000 pounds per acre, i.e., per 2,000,000 pounds of soil.

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The seeds were planted on October 10, 1942. On germinating, the seedlings were thinned to three per drum. Since the drums were 13½ inches in diameter, there was one square foot of soil surface for the three plants. Between the planting date and November 2, the average soil moisture content in all drums was maintained between 14 and 18 per cent; i.e., when daily weight records indicated the average moisture content had been depleted to 14 per cent, sufficient tap water was added to the surface of the soil to bring the average moisture percentage to 18.0–18.5 per cent. Subsequent to November 2, half of the drums in each salt level were continued on the above irrigation schedule and the other half were not irrigated until the average soil moisture content was depleted to near the wilting percentage—yet not sufficiently depleted to induce wilting of the plants. The latter condition was reached on November 9 and the plants in this dry soil were then irrigated during that night and the next morning. Plant samples were taken from three or four drums in each of the four treatments at sundown on four days prior to this irrigation and on three days subsequent to it, in order to ascertain the shifts taking place in the starch reserves of the plants accompanying soil moisture depletion and following irrigation of the desiccated soil. Each plant was weighed separately so that there were either nine or twelve observations on plant growth for each treatment at each harvest to be used in the statistical reduction of the data. The weighed plants were separated into stems and leaves, and prepared for preservation by rapid desiccation in a forced draft oven at 70 degrees C. All material of a given tissue from plants of a specific treatment was pooled in order to have sufficient for two or three analytical replicates. Hence, an estimation of sampling error for starch was not possible.

Starch analyses were made on the tissue after it had been ground sufficiently fine in a ball mill to pass a 100-mesh screen. A modification of the method described by Nielsen (14) was used in the starch assay; bean starch was extracted and purified for use as the colorimetric standard.

Fig. 1 shows the trends of the average soil moisture content in the drums of each of the four treatments during the experimental period. Within each series (wet or dry) there was greater depletion of the soil moisture in soil without added NaCl, but even at the minimal value, the average soil moisture content was appreciably above the wilting percentage of 6.1 per cent. Hereinafter, the drums containing soil which was kept relatively moist will be designated as constituting the "wet series"; and those in which the soil was permitted to dry out prior to the irrigation will be designated as constituting the "dry series".

Plants were harvested at sundown (6 p.m.) on the evenings of November 2, 5, 7, 9, 10, 11, and 13. Fig. 2 shows the trends of the average dry weights of tops per plant during this period. Plants grown in the saline soil were significantly smaller than those in the non-saline soil regardless of moisture treatment; and the differential due to salt addition increased with time. By November 9, the plants on the "dry

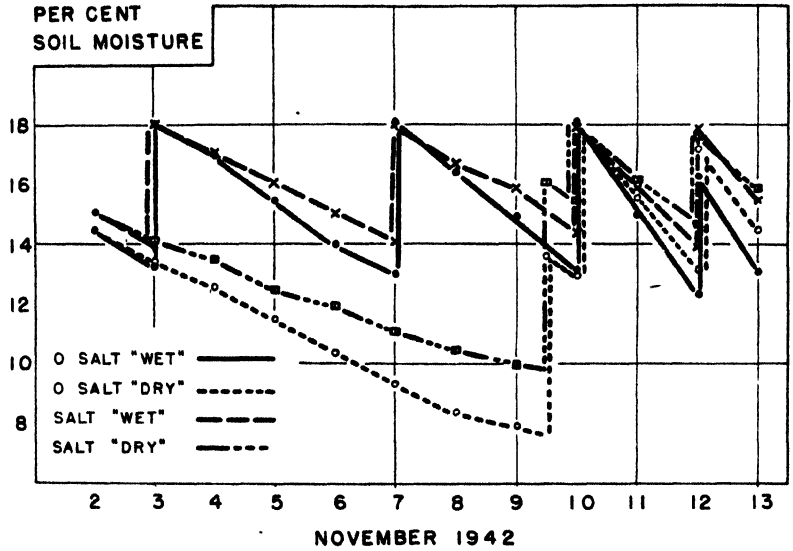

FIG. 1. The range of average soil moisture contents observed during the course of the experiment. Vertical lines designate time of irrigation.

series" of soils within each salt level were significantly smaller than the corresponding plants on soil kept relatively moist. Likewise, daily

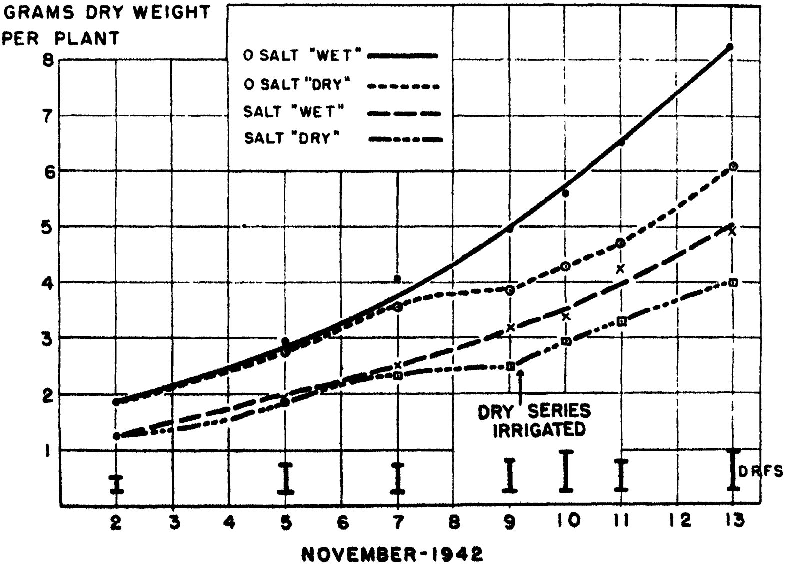

FIG. 2. The trends of average dry weights per plant for the various experimental conditions. (D.R.F.S.: Difference required for significance).

measurements on rate of leaf expansion during this period showed that growth of developing leaves was significantly inhibited by soil moisture depletion to a greater extent than could be accounted for by concentration of the soil solution. There is a break in the curves for dry weight of plants in the two "dry series", coincident with the irrigation following the harvest on November 9. This demonstrates the marked change in growth rate as a result of the irrigation. It should be stressed that the plants in the "dry series" did not wilt at any time. They did, however, show appreciable phototropism when the soil moisture had become appreciably depleted (November 6 through 9). Whereas the plants in the "wet series" maintained their leaf blades at approximately right angles to the sun's rays, those in the "dry series" oriented their leaf blades parallel to the sun's rays.

As might be expected, the treatments used in this experiment induced marked differentials in the percentage of dry matter in the plant tissues. Fig. 3 shows that regardless of salt treatment the percentage of dry matter became appreciably higher in the stems of the plants in the "dry series" than in those of the "wet series", but this differential was practically eliminated two days after the irrigation. The leaves tended to show a similar relationship, but in the leaves there continued to be an appreciable differential between the "wet" and the "dry series". It is noteworthy that within a given moisture regime, plants on the saline soil rather consistently had a lower percentage of dry matter than those on the non-saline soil. This has been noted previously when NaCl was the main salt present in the substrate (6).

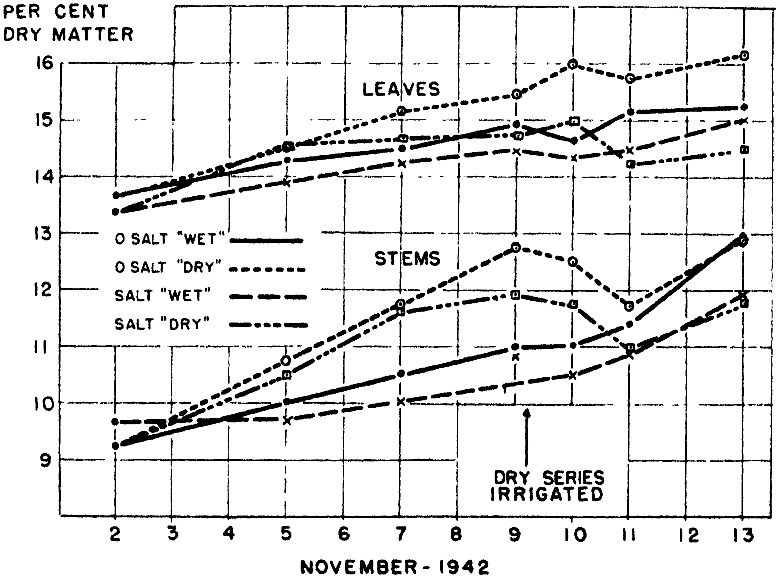

FIG. 3. The trends of percentage dry matter for the various experimental conditions.

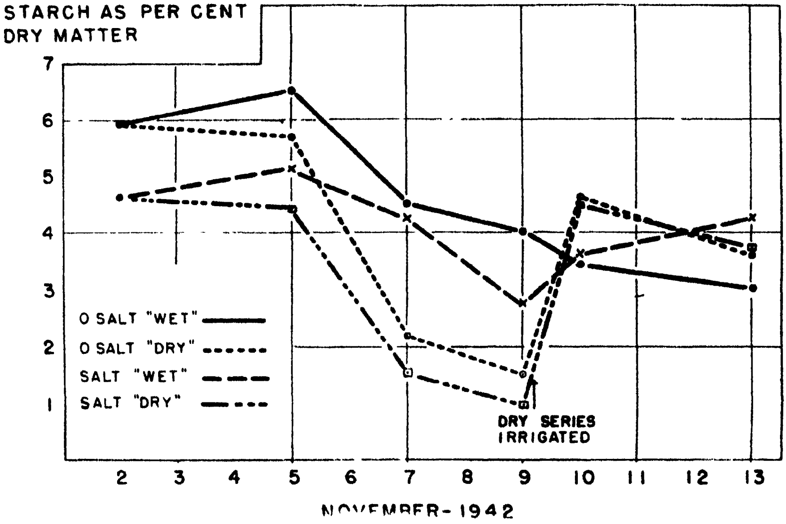

FIG. 4. The starch content of the leaves of plants harvested periodically from the four treatments.

Fig. 4 shows the trends of starch reserves in the leaves. Similar trends were found for the stems but the percentage content was not as high nor the range as great as found for the leaves. In the "wet" series of plants, there tended to be a gradual decrease in percentage of starch reserves with time, with the exception that the plants in the saline soil showed a reversal of this trend toward the end of the experimental period. In the two "dry" series the starch reserves of the leaves showed a marked depletion as the soil dried out, and was quite low by November 7 when the average soil moisture was still appreciably above the wilting percentage. (See Fig. 1.) The pronounced build-up in starch reserves immediately following irrigation, regardless of soil salinity, is especially striking. These marked variations in starch reserves in the "dry" series of plants appear to be coincident to leaf orientation due to phototropism. On the days during the latter part of the dry spell when leaf orientation was especially evident on the "dry" series of plants, starch reserves in the leaves and in the stems were found to be low. Immediately following the irrigation the stimulus inducing this orientation was removed, and the leaves immediately built up an appreciable starch reserve. Although these two responses varied concomitantly, direct causation between them was probably not involved; but rather, they both appeared to have been induced by moisture stresses within the plant.

It is believed that variations in aerial environment cannot account for the variations in starch reserves during this period. During this time solar radiation at Riverside[2] averaged 340 gram-calories per square centimeter with a maximum daily fluctuation from this average of only 10 per cent. Owing to the filtering action of glass, obstruction of sash bars, and dust on the glass, solar radiation within the greenhouse as indicated by a pyrheliometer averaged only 185 gram-calories per square centimeter with a maximum daily fluctuation of 10 per cent of this mean. The maximum daily temperature averaged 88 degrees F with a maximum daily fluctuation from this mean of 8 per cent; and the minimum daily temperature averaged 60 degrees F with a maximum daily fluctuation of only 5 per cent of this mean.

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[2] Data supplied by courtesy of the Citrus Experiment Station, University of California, Riverside, California.

For the most part, plants in the saline soil had a lower starch content in their leaves than those on the non-saline soil. A study of paired observations on this comparison showed this differential to be well beyond the requirements of .01 significance for the data prior to the irrigation; and significant above the .05 level when all paired observations were taken. The seemingly anomalous shift in this relation in the "wet" series of plants for the latter harvests is without explanation.

Results at this Laboratory (12) have pointed to the conclusion that, for the most part, the presence of the usual components of a saline soil in the substrate does not induce specific symptoms on the plant, but, rather, brings about a general stunting of the plant as though a water deficit were involved. Studies (7, 16) in which potometers have been attached to roots in order to measure water uptake have shown that water absorption by roots varied inversely with the osmotic pressure of the root medium. Rosene (16) found this to be the case whether sucrose or a neutral salt was used to build up osmotic pressure in the growing medium. Eaton (3) using divided root systems, also showed that water absorption by roots is decreased as the osmotic pressure of the culture solution is increased, and that this relationship held regardless of whether chloride or sulfate was the preponderant anion. Long's data (10) not only support the above, but also show that sucrose solutions isosmotic with NaCl solutions have practically the identical effect in decreasing water absorption by roots. Since sucrose is not regarded as being chemically toxic to the absorbing membranes of the roots, this finding lends considerable support to the view that one of the main effects of salt in the substrate is a physical retention of water from the plant.

Ayers, *et al.* (1), presented data on the osmotic concentration of the soil solution at various moisture contents of this same soil which had been correspondingly treated in another experiment with beans. The osmotic pressure of the soil solution was found to be as follows:

Soil Horizon in Drum (Inches)	No Added NaCl		0.2 Per Cent Added NaCl	
	7 Per Cent Soil Moisture (Atms. O.P.)	15 Per Cent Soil Moisture (Atms. O.P.)	7 Per Cent Soil Moisture (Atms. O.P.)	15 Per Cent Soil Moisture (Atms. O.P.)
0–5	1.67	0.78	9.80	4.57
5–10	4.26	1.99	20.5	9.57
10–15	5.59	2.61	42.7	19.9

It may be argued that the growth characteristics observed due to soil desiccation were almost entirely the result of concentrations of the soil solution. In the light of the above data, the relative trends of all curves in Fig. 2 showing accumulation of dry matter would fit such an explanation. However, such an explanation does not fit the relative trends of the curves pertaining to percentage of dry matter given in Fig. 3. These latter values tend to reflect the status of soil moisture availability since they are a partial index of the succulence and water relations within the plant tissues. Thus, for any given horizon, the salt content of the soil solution in the "wet" series with 0.2 per cent salt in the soil was definitely higher than the maximum concentration of salt attained in the soil solution of the "0-salt", "dry" series. Desiccation of the soil had a much more marked effect upon the percentage of dry matter in the plants than did salt content of the soil solution *per se*. As shown in Table I, the mean differential between soil moisture levels (1.26) was significantly larger than the one between soil salinity levels (0.42).

TABLE I—DIFFERENCES IN PERCENTAGE DRY MATTER IN STEMS FOR A GIVEN COMPARISON

Comparisons		Date of Harvest (See Fig. 3)				
		Nov 5 (Per Cent)	Nov 7 (Per Cent)	Nov 9 (Per Cent)	Nov 10 (Per Cent)	Mean (Per Cent)
Between soil moisture levels	"O—salt wet" vs. "O—salt dry"	0.73	1.33	1.81	1.50	1.26*
	"salt wet" vs. "salt dry"	0.85	1.53	1.07	1.29	
Between soil salinity levels	"O—salt wet" vs "salt wet"	0.33	0.34	0.12	0.59	0.42*
	"O-salt dry" vs. "salt dry"	0.21	0.14	0.86	0.80	

*The mean difference for soil moisture levels is significantly greater than that for salinity levels (P <.01).

The relative trends of the curves in Fig. 4 showing starch content cannot be explained entirely on the basis of variations in concentration of soil solutions. For example, within a given moisture regime there were relatively small differences in starch content of the leaves associated with a large differential between the concentration of soil solutions from the salt-free and salt-added soils. However, between moisture regimes within a given salt treatment there was a marked divergence in the trend of starch reserves in the leaves, and this divergence was much more closely related to soil moisture content than to salt concentration of the soil solution. In accordance with the findings of Spoehr and Milner (18), it seems probable that the observations on starch disappearance in the plants during soil desiccation indicates that the plants were subjected to a moisture stress appreciably before the average soil moisture approached the wilting percentage and even though the plants showed no symptoms of wilting. These observations are not in harmony with findings that all soil moisture between the wilting percentage and field capacity is equally available to plants and that variations within this soil moisture range will not be reflected in plant growth and crop yields.

The presented data are corroborated by the work of Schneider and Childers (17) who found that when the moisture content of soil in which apple trees are grown approaches the wilting percentage, there is a corresponding decrease in the rate of apparent photosynthesis in the leaves and an increase in the rate of respiration. These data also lend support to those (2, 4, 9, 11) finding modifications in plant growth processes when plants are subjected to a soil moisture stress, but are not wilting.

SUMMARY

Dwarf Red Kidney bean plants were grown in a non-saline soil and also in this same soil with 0.2 per cent NaCl (dry weight basis) added. Two moisture regimes were studied, viz., (a) in one series ("wet") the average soil moisture content in the drums ranged from 14.0 to 18.0 per cent; and in the other ("dry") (b) the soil was permitted to dry down to near the wilting percentage prior to irrigation.

Four plant samplings (leaves and stems) were made during the drying-out period and three subsequent to irrigation.

In contrast with the plants in soil kept continuously "wet", there was a marked, progressive depletion of starch in the leaves of plants grown in soil which was permitted to approach the wilting percentage prior to irrigation. Regardless of whether salt was present or not, there was a marked build-up of starch reserves immediately following the irrigation. For the most part, plants in the saline soil had a lower starch content in their leaves than those on the non-saline soil.

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Comparative Studies of Varieties of Certain Vegetables for Dehydration

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THE entrance of the United States into all-out war has necessitated large-scale dehydration of certain vegetables for the use of our own and allied armed forces. Present production is almost exclusively for such use and is limited to a few important vegetables and fruits, but there is a distinct possibility that limitations upon canning may make it necessary to resort to drying as a rather general means of preserving fruit and vegetable foods for the use of the civilian population. There is consequently an imperative demand for information in regard to the "best" varieties of the various vegetables for dehydration.

This laboratory has undertaken studies designed to supplement the rather meagre information available in regard to the suitability of the various varieties of the more important vegetables for drying purposes. The present paper is a summary of the findings of the first season's work with respect to the comparative quality of the products obtained from groups of varieties of some of the more important vegetables that were dehydrated under uniform controlled conditions. Details of technique are largely or wholly omitted here but are stated in full in the complete papers to which reference is made.

POTATOES (1)

The primary purpose of this study was to obtain information upon two questions of primary importance in connection with the filling of army requirements for dehydrated potatoes. The first of these was about the comparative suitability of the various varieties for drying purposes; the second, regarding the range of variation in quality of dehydrated product to be found in a variety as grown in various producing districts. Material used in the study consisted of stock of U. S. No. 1 grade, grown by cooperators in the National Potato Breeding Project in the states of Washington, Idaho, Colorado, Pennsylvania, Maine, and, at two locations each, in Michigan and New York. Each Experiment Station supplied the varieties that are of primary commercial importance in its particular district. The total number of varieties was 20, and included all the older commercially important varieties and a few of the more promising recent introductions. The more widely grown varieties were represented by material from most of the nine locations. All of the material was assembled at the Bureau of Plant Industry Station, Beltsville, Maryland, where each bulk lot was subdivided into three subsamples ranging from 50 to 100 pounds in size. All the subsamples were given code numbers and randomized before delivery to the dehydrator so that triplicates were separately handled throughout preparation, drying, and the subsequent cooking and grading. This method of handling afforded a check upon variations in the techniques employed. The total number of subsamples was 294.

The techniques of preparation, dehydration, and subsequent handling and storage of the material were carefully standardized at the outset and rigidly adhered to throughout the work (1). The interval between dehydration of the material and the cooking and grading was about 9 weeks. Data obtained upon each subsample included specific gravity of the fresh entire tubers, percentage of peeling and trimming loss, dry yield as percentage of fresh stock and of pared, trimmed potatoes, and amounts of water absorbed in refreshing and cooking. Factors considered and separately scored in grading the products were: color and general attractiveness of the dry product, and color, texture or consistency, palatability and flavor of the sample as refreshed and prepared as riced potatoes. Final rating of each sample was obtained by averaging all scores on all factors for the triplicate subsamples, as noted by a panel of six judges. The final results are assembled in Table I.

TABLE I—Rating upon Quality of Dehydrated Products of Nineteen Varieties of Potatoes (1 = Excellent, 2 = Very Good, 3 = Good to Very Good, 4 = Good, 5 = Fair)

Variety	Place Grown								
	Maine	Pennsylvania	Idaho	Michigan (Rogers City)	Michigan (Lake City)	Colorado	Washington	New York, (Ithaca)	New York (Elba)
Katahdin	2	3	2	2	2	1	5	3	2
Sebago	1	3	5	2	—	—	2	—	—
Irish Cobbler	2	3	4	4	2	—	—	—	—
Chippewa	1	2	2	2	2	—	—	2	3
Green Mountain	1	1	—	2	—	—	—	1	1
Sequoia	1	2	—	—	—	—	4	—	—
Houma	1	2	4	—	—	—	—	—	—
Warba	1	3	—	—	—	—	—	—	—
Earliane No. 2	4	5	—	—	—	—	—	—	—
Pontiac	1	—	4	—	4	—	2	—	—
Triumph	1	—	2	—	—	1	—	—	—
White Rose	2	—	—	—	—	—	4	—	—
Rural Russet	—	1	—	2	1	—	—	—	—
Rural New Yorker	—	1	—	—	—	3	—	—	—
Russet Burbank	—	—	1	—	—	—	2	—	—
Pawnee	—	—	—	—	—	2	—	—	—
Mohawk	1	—	—	—	—	—	—	—	—
Pioneer Rural	—	—	—	—	—	—	—	1	1
Red Warba	1	—	—	—	—	—	—	—	—

It is obvious from the table that no single variety showed outstanding superiority in quality of product throughout the range of locations in which it was grown, and that no single district produces potatoes of high quality, regardless of variety. All the varieties employed in the experiment are potentially capable of producing dehydrated products of excellent quality when grown under conditions to which they are well adapted but are of lower quality when grown under conditions to which they are not well adapted.

The specific gravity of the various lots of fresh potatoes ranged between 1.105 and 1.060 as extremes. There was a very definite correlation between specific gravity and consistency of the cooked product; raw stock of high specific gravity gave larger yields of dry product, absorbed smaller amounts of water in refreshing and cooking, and had more desirable consistency (dryness or mealiness) when cooked, than stocks of lower specific gravity. Color and flavor varied independently of specific gravity, so that high specific gravity of raw material does not absolutely determine high quality of product.

The results of a single season's work indicate that a dehydrator operator planning to process potatoes grown in Pennsylvania might well use Green Mountain, Rural Russet and Rural New Yorker as first choice with Chippewa, Sequoia and Houma as second-choice varieties. For stock grown in Michigan, Rural Russet would be first choice, with Irish Cobbler, Green Mountain, Chippewa, Katahdin and Sebago as second; for New York, Green Mountain and Pioneer Rural first, with Katahdin and Chippewa second; for Washington, Russet Burbank and Sebago first; for Idaho, Russet Burbank first, with Sebago, Triumph and Katahdin second; and for Colorado, Triumph and Katahdin first, with Pawnee second. For Maine, eight or nine varieties were of equally good first-rank quality, as might be anticipated from the fact that most of them were originated in that State and are well adapted to its conditions.

At the present time a study of the suitability for dehydration of early-crop potatoes from the more important Southern producing districts is in progress in the laboratory. The methods of procuring and handling the material employed are identical with those used with the fall-crop material from the Northern producing states. Where possible, two sets of samples were obtained from each district, one dug at the time the crop was being harvested for market, the other, 2 to 3 weeks later when the tubers had matured and the vines were dying or dead. All the samples dug at the time the crop was being harvested for market were obviously immature, as shown by their small size, tender, peeling skins, proneness to decay, and, above all, by their low specific gravity, which ranged from 1.042 to 1.060. All of this immature material, regardless of variety or place of growth, gave very low yields of dry product of rather poor color, which, when refreshed, was of mediocre flavor and extremly poor, waterlogged and soggy or waxy consistency. The mature samples from the same plots show decided improvement in all respects. While the work is still in progress, the results obtained make it clear that a dehydrated product of satisfactory quality cannot be made from physiologically immature potatoes.

Onions (2)

The primary requirement in a satisfactory dehydrated onion for military use is that it shall have a high degree of pungency or "hotness", since the material will be employed primarily as a flavoring in meat and vegetable mixtures and only in minor degree as a separate vegetable. It is consequently of very considerable interest to dehydrator operators and purchasing agencies to have information in regard to the quality of dehydrated product obtainable from various varieties and especially as to their retention of pungency and ability to "spread" their flavor when added in small quantities to other foods. The degree to which desirability of a variety for drying purposes may be affected by the climatic and soil conditions under which it is grown or by storage previous to drying are also questions upon which more information is urgently desired. The present work was planned to secure information upon these questions.

Ten varieties of onions, representing very strong or pungent, moderately strong, and mild types were used in the work. Several of the varieties were represented by two or more selections or strains and by material grown in two or three districts. Material of Ebenezer was grown in Maine, Colorado and New York, that of Barnett and of Scott County Globe, in Maine and Colorado, thus giving opportunity for study of any differences in product attributable to widely differing conditions of growth. Four of the varieties grown in Maine had been produced in an experiment employing five differing rates of fertilizer application upon three types of soil, hence there was opportunity to study effects of these factors. Altogether there were 75 lots of material, all of which were assembled at Beltsville and prepared, dehydrated, and subsequently reconstituted and cooked for examination by a uniform, standardized method.

The material was prepared and cooked for comparison and grading in three forms, as a stewed vegetable, as a soup, and as a flavoring ingredient added in definite amounts to a neutral-flavored vegetable (potato). Factors considered in grading were color, texture or consistency, palatability and flavor, and "spreading" capacity or ability to impart pungency and flavor to neutral material.

Considered as a flavoring agent, Ebenezer ranked first, giving most pronounced and pungent flavor; Barnett, Southport Yellow Globe, Early Yellow Globe, and Golden Globe ranked closely together somewhat below Ebenezer; Red Creole had very pleasant, distinctive flavor, but was less piquant than the group last named. Southport White Globe and Scott County Globe were only fair in flavoring power and would require use of larger quantities than of those previously named to give equally good results. Sweet Spanish and Crystal Wax were so characterless and lacking in pungency as to be valueless for flavoring purposes. As stewed onions or in soups, the varieties ranged from strongly pungent, as Ebenezer and Barnett, downward to mild and rather characterless as Sweet Spanish. All were very acceptable in flavor except Crystal Wax, which had an unpleasant, abnormal flavor.

Considerable loss of pungency occurs in all types of onions in the course of dehydration through volatilization of the essential oil. The amounts remaining in the various varieties appear to be roughly proportional to those originally present, with the result that the dry products compare with one another about as the fresh material did, with respect to pungency. The basic quality and character of the flavor was not altered (except in Crystal Wax), only its intensity being affected.

No differences in color, texture, flavor or pungency could be detected between samples of dehydrated product of the same variety grown in widely separated districts, nor were there detectable differences in quality of product grown upon different types of soil and with various amounts of fertilizer..

Four varieties were employed in a study of effect of storage upon drying behavior and quality of dry product. Portions of each were dehydrated on November 24, and untreated bulk samples placed in storage at 32, 40, 45, and 50 degrees F. Part of each storage lot was dehydrated after 26 days, the remainder after 114 days. Amounts of decay occurring at the different temperatures varied widely, but the usable sound material made products of good quality with no increase in tendency to discolor during or subsequent to drying. Yields of dry product varied widely, those from the firm, pungent, long-keeping varieties, such as Creole, Ebenezer, Scott County Globe, Golden Globe and Barnett, being highest. Sweet Spanish was lowest, and the other varieties were intermediate.

SWEET CORN (3)

The possibility that governmental restrictions upon the use of tin and steel for the manufacture of cans might curtail the canning of sweet corn made it seem desirable to determine the quality of the dehydrated products obtainable from some of the more generally grown varieties. Thirty-four varieties (18 of them yellow, 16 white) were grown together at the Plant Industry Station, Beltsville, Maryland, for use in the work. Two plantings, separated about 10 days in time, were made upon differing soil types, each area being sufficiently large to supply a complete series of good-sized samples differing by 1 or 2 days in stage of development and extending over the whole period of usable maturity. Studies were made throughout the season upon field performance of the varieties: height, vigor, disease resistance, adaptability to soil and climatic conditions, period from planting to usable maturity, and yields. The varieties showed a much greater range of difference in some of these characters than in quality of product.

The dehydrated material of each variety consisted of a series of samples, taken at short intervals, in duplicate, extending over the range of usable maturity. These were examined and graded for color and general appearance in the dry condition, then rehydrated, cooked, and again graded for color, consistency, degree of tenderness or toughness of pericarp, presence or absence of starchiness, and flavor. Comparisons between the various stages of maturity permitted selection of the stage at which each variety had its optimum quality and greatest desirability. This most desirable stage was quite uniform for all varieties, and was that at which the grains had attained an average dry weight of 40 to 50 per cent of the mature dry weight of grains of the variety. It is identical with the stage at which corn is in optimum condition for canning in whole-grain style. Younger corn was sweet but watery and poor in body, older stages were progressively tougher, more starchy, and less sweet and appealing in flavor.

In the final comparisons as to desirability for drying purposes, each variety was considered only at its optimum stage for use. At this stage, a large number of varieties showed only very small differences in basic quality and palatability. Eight varieties were slightly superior to the others; these were Aristogold Bantam Evergreen, Bantam Evergreen, Golden Cross Bantam, Sachem, Soobred, Narrow Grain Evergreen, Country Gentleman, and Silver Cross Evergreen. Seventeen others were not quite equal to the first-named group but were rated as very good. These were Alleghany, Charlevoix, Golden Bantam, Golden Colonel, Golden Hybrid 2439, Ioana, Marcross, Spancross, Tendergold, Top Cross Whipple Yellow, Tristate Hybrid, Country Gentleman 19x24, Country Gentleman Hybrid Illinois 8x6, Honey June, Pontiac, Silver Cross Country Gentleman, and Narrow Grain Hybrid 26x15. A third group was palatable and acceptable but lacked the sweetness and fineness of flavor of the preceding groups; this included Early Crosby, The Burpee, Howling Mob, Whipple Early Yellow, Whipple Early White, Stowell Evergreen, and Stowell Evergreen Hybrid 14x13. Two market varieties, Adams Large Improved and Truckers' Favorite, were quite inferior in flavor, starchy, with objectionable prominence and toughness of pericarps.

The number of varieties that make very good to excellent products when dehydrated at the optimum stage of maturity is so large that a dehydrator operator located in any of the important sweet corn producing districts will find in the list a number of varieties that are known to be well adapted to his particular locality.

SNAP BEANS (4)

The work with snap beans was preliminary in character and no attempt was made to include all varieties; the 13 varieties used were so chosen as to represent garden, market, and canning types. They were grown at the Plant Industry Station at Beltsville. Duplicate plantings 2 weeks apart were made, one upon a clay loam, the other on a sandy loam, both of which gave very good crops of all varieties. There were no detectable differences in drying behavior or quality of product between the two plantings.

Material of each variety was harvested in quantity and separated in the laboratory into five stages of development covering the whole range of usable maturity. The first of these was "baby" beans in which enlargement of the seeds had barely begun and the pericarp made up 95 per cent or more of the total weight of the pod; the last stage consisted of the oldest pods possible to obtain with reasonably good color and freedom from toughness and woodiness. Each stage was prepared and dehydrated separately in order to permit determination of the stages of development giving dried products of optimum quality.

"Baby" beans consisting almost wholly of pericarps made very unsatisfactory products regardless of variety used or technique of drying employed. Such material rehydrated imperfectly, hence was tough, and was usually flavorless when not astringent and bitter. The desirable range in maturity for beans for drying begins when the seeds have such size that they make up about 9 to 10 per cent of the fresh weight of the pod; it ends, for most varieties, when they are of such size that they make up 25 to 30 per cent of the fresh weight of the pod. The upper limit varies with variety and to some degree with the season, and is determined by the development of objectionable amounts of fiber in the pericarp.

The comparative ranking of the varieties in suitability for dehydration was determined by grading all samples of each variety separately in dry condition upon color, general appearance, and odor, then refreshing, cooking, and grading the cooked material upon general attractiveness and color, texture (tenderness or toughness), palatability, and flavor. Combined grades of all samples of the variety at all usable stages of maturity determined its comparative overall suitability for dehydration.

Three varieties of the 13 tested, Asgrow Stringless Green Pod, Lazy Wife Pole, and Dwarf Horticultural (Speckled Cranberry), were best by reason of superiority in all the factors considered. Three additional varieties, Bountiful, Asgrow Stringless Valentine, and Stringless Kidney Wax, were considerably below the three first named in attractiveness of color but were good in texture and flavor. The remaining varieties, Blue Lake, Ideal Market, Kentucky Wonder, White Seeded Rust-Resistant Kentucky Wonder, U. S. No. 5 Refugee, Tennessee Green Pod, and Pencil Pod Black Wax, made inferior and unsatisfactory products. Their most serious defect was toughness and presence of fiber in the pericarp and failure to rehydrate fully after drying, but most of them were also unattractive in color, both in dry and cooked condition. While most of these were fair or acceptable in flavor, their poor color and tough, fibrous character made them very poor products. Modifications of the preparatory treatment before drying considerably improved color and appearance, but no material improvement in texture or reduction of toughness of the tough varieties was obtained by increasing the period of precooking before drying or by modifying the refreshing and cooking procedures. "Toughness" is due to inherent structural characters of the variety not capable of much modification by such treatments. To be acceptable for dehydrating purposes, a variety must be one in which development of the fibrous layer in the side wall of the pericarp is minimum in amount and begins late in the growth of the pod.

SWEETPOTATOES

The sweetpotato is potentially highly important as raw material for dehydration for several reasons: it is an important crop throughout the South Central, Lower Atlantic, and Central Atlantic States and its production could be very largely increased if demand justified such increase; the readiness with which material can be kept in good condition in storage permits a long working season for dehydrators using it; its total solids content and total carbohydrate content in fresh condition are higher than for any other vegetable, not excepting the white potato; and some of the more deeply colored varieties, especially after curing and storage, have a very high carotene (pro-vitamin A) content.

A rather comprehensive study of the drying of the sweetpotato was reported by Caldwell, Moon, and Culpepper in 1938 (5). Methods of preparing and drying the product in a variety of forms were worked out, and a comparative study of suitability for dehydration and of quality of the dried product was made upon all available named varieties and strains as well as a number of strains and selections which were under test to determine whether they had sufficient merit to warrant introduction. The results showed that the sweetpotato is especially promising material for dehydration and that a considerable number of the generally cultivated varieties give products of good to excellent quality.

The work done during the past year continues and supplements the earlier study, primarily for the purpose of securing information upon the drying quality of a number of varieties not previously studied, especially some recent introductions and selections having deeply colored yellow or orange flesh. Among these were Maryland Golden and Orange Little Stem, orange-fleshed selections from Yellow Jersey and Little Stem Jersey, respectively; Nancy Gold, a selected strain of Nancy Hall; and two selected strains of Porto Rico, namely, Kansas 40 and Unit I. Material of these and about 30 additional varieties and strains, including most of the older standard varieties, was obtained from associates in the Vegetable Investigations project, and all were dehydrated at one time. The methods employed were essentially identical with those employed in the earlier work (5), so that the results may be combined and considered as a whole. This has been done in the following tabulation, which includes all named varieties that have been studied in this laboratory with respect to drying quality. The factors considered in classifying the varieties were: retention of full, unmodified flavor; good, smooth texture with freedom from toughness, starchiness, or excessive fiber; attractive color in both dry and cooked condition; and freedom from excessive or pronounced tendency to darken in drying or subsequent cooking. In general, it will be seen that the ranking of varieties for drying purposes rather closely parallels their quality as fresh or canned products.

First Rank. Excellent. Nancy Hall, Myers Early, Mullihan, Mameyita, Nancy Gold.

Second Rank. Very Good. Big Stem Jersey, Yellow Jersey, Yellow Strasburg, Porto Rico, Red Bermuda, Virovsky, Menes Moeder, Orange Little Stem, Maryland Golden, Kansas 40, Unit I Porto Rico, North Carolina No. 1.

Third Rank. Good Red Jersey, Gold Skin, Vineland Bush, Creola, Key West, Pumpkin "Yam", Vineless Pumpkin "Yam", Japanese "Yam", Wenholz I.

Fourth Rank. Fair. Southern Queen, Ballinger Pride, Miles, Florida, Norton, Red Brazil, Triumph, Director.

Fifth Rank. Unpromising. Belmont, Catawba White, Catawba Yellow, Dahomey, Early Carolina, General Grant, Georgia, Gros Grandia, Haiti "Yam", Pierson, Purple "Yam" (Nigger Choker), White "Yam", Yellow "Yam", Vineless "Yam".

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Some Effects of Micro-Elements on Growth and Storage of Carrots and Turnips

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THIS paper is a report of the effect of soil applications of boron, copper, manganese, and zinc on the storage quality of carrots and turnips grown in three different soil types. Certain determinations which are usually associated with storage quality are included.

The work reported was carried out during 1942–43 following preliminary trials in 1941–42 which showed similar trends.

MATERIALS AND METHODS

Registered carrot seed, Chantenay half-long, and Swedish turnip, Laurentian, were planted on three distinctive soil types namely, an intensively cultivated, well limed peat soil, a medium clay (Milner clay) and a light sandy loam (Alderwood type). These soils are described in a Soil survey of the Lower Fraser Valley by Kelley and Spilsbury (5).

Before the fertilizer treatments were applied an estimate of the available soil nutrients were made by the method of Spurway (10) and the reaction of the soil determined with a glass electrode.

TABLE I—ESTIMATE OF SOIL FERTILITY BY THE SPURWAY METHOD IN THE THREE TYPES OF SOIL USED IN THE EXPERIMENT

Soil Type	pH	Nutrients (Pounds Per Acre/6 Ins)			Calcium
		Nitrogen	Phosphorus	Potash	
Peat	6.20	40	32	120	1460
Clay	5.20	16	136	136	1240
Sand	6.30	32	17	24	1460

All three soil types are used extensively for vegetable production and are within a radius of 15 miles so that climatic differences would be negligible.

On each soil type a block was selected and laid out in a 5 x 5 Latin square. Each of the five treatments used including the control was thus repeated five times making in all 25 plots in each block. All plots were given a basic treatment of a 5–10–5 fertilizer at the rate of 1000 pounds per acre. The control plots received no further treatment. The other treatments were boron, as boric acid, at the rate of 50 pounds per acre; copper as, copper sulfate, at the rate of 50 pounds per acre; manganese as the sulfate, at the rate of 30 pounds per acre, and zinc sulfate at the rate of 15 pounds per acre. The size of the individual plots was 1/100 of an acre. All treatments were randomized within the limits allowed by the latin square.

The carrots were sown June 6, 1942 and the turnips on June 22, 1942. They were harvested on October 7 and 22 respectively, at which time they appeared to be of comparable maturity.

On harvesting, each plot was recorded separately. The ratio of root to top was determined by selecting at random 100 individuals and dividing the weight of top into that of root. Two hundred and fifty carrots and 100 turnips were also selected at random from each plot and placed in sacks and stored in a good root cellar. The roots were sorted periodically throughout the winter and counts made of those in good, bad and fair condition. Only the good ones were saved each time and final counts of good marketable carrots and turnips were made on March 5 and 22 respectively.

All data were treated statistically by the analysis of variance for the latin square as outlined by Patterson (9).

Further samples were taken into the laboratory for chemical analyses, which will be reported on in a later paper.

In order to indicate associations with keeping quality the following determinations are shown. In carrots, total sugars as determined by the method of McCance *et al* (6) and dry-weight by drying in a vacuum oven. In turnips, the total carbohydrate is shown. The preliminary experiments the previous year had shown that turnips grown on the peat soil were unsuitable for storage purposes. They broke down rapidly, despite treatments, and could not logically be compared with those from the other two areas.

RESULTS

Carrots:—The results of the experiment are shown below in tabular form, Tables II to VI.

It can be seen from Table II that in the peat soil boron, copper and zinc all increased yield and size of roots over that of the controls. Zinc had the most profound effect. They also increased weight of roots in relation to tops. On the other hand all the microelements used decreased sugar content and dry weight. The keeping quality of the carrots from the boron, manganese and zinc plots was enhanced. The

TABLE II—THE EFFECT OF APPLICATIONS OF BORON, COPPER, MANGANESE, AND ZINC ON CARROTS GROWN IN THE PEAT SOIL

	Soil Treatment				
	Control	Boron	Copper	Manganese	Zinc
Total yield roots (tons per acre)*	14.30 ±0.309	15.32 ±0.309	15.60 ±0.309	14.40 ±0.309	16.78 ±0.309
Average weight tops (pounds)	0.200	0.186	0.184	0.164	0.196
Average weight roots (pounds)	0.212	0.226	0.227	0.215	0.234
Ratio root/top	1.06	1.22	1.24	1.31	1.20
Dry weight roots (per cent)	11.825	11.208	11.174	10.705	11.368
Total sugars (per cent fresh weight)	7.44	6.94	6.80	6.08	7.00
Total carbohydrate (per cent)	9.20	9.16	8.96	8.54	8.72
Percentage marketable after 5 months storage†	51.30 ±2.01	58.50 ±2.01	52.20 ±2.01	57.30 ±2.01	65.00 ±2.01

*Critical difference in yield P = 0.05 = 1.024 tons per acre.
†Critical difference storage = 0.05 = 5.902 per cent.

TABLE III—The Effect of Boron, Copper, Manganese, and Zinc on Carrots Grown in a Clay Soil

	Soil Treatments				
	Control	Boron	Copper	Manganese	Zinc
Total yield roots (tons per acre)*	11.05 ±0.524	11.25 ±0.524	13.80 ±0.524	10.50 ±0.524	11.60 ±0.524
Average weight tops (pounds)	0.187	0.167	0.228	0.172	0.190
Average weight roots (pounds)	0.205	0.209	0.257	0.196	0.216
Ratio root/top	1.10	1.25	1.13	1.15	1.14
Total sugars (per cent fresh weight)	7.57	8.07	6.07	6.91	8.64
Percentage marketable after 5 months storage†	62.00 ±2.64	84.00 ±2.64	82.00 ±2.64	41.00 ±2.64	70.00 ±2.64

*Critical difference P = 0.05 = 1.59 tons per acre.
†Critical difference P = 0.05 = 7.92 per cent.

TABLE IV—The Effect of Boron, Copper, Manganese, and Zinc on Carrots Grown in a Sandy Loam

	Soil treatments				
	Control	Boron	Copper	Manganese	Zinc
Total yield roots (tons per acre)*	8.25 ±0.347	9.05 ±0.347	10.15 ±0.347	10.05 ±0.347	9.40 ±0.347
Average weight tops (pounds)	0.0512	0.056	0.059	0.055	0.061
Average weight roots (pounds)	0.155	0.168	0.191	0.188	0.174
Ratio root/top	3.03	3.03	3.27	3.40	2.84
Dry weight roots (per cent)	12.21	11.92	13.71	11.84	12.85
Total sugars (per cent fresh weight)	9.46	7.45	8.50	8.33	9.29
Percentage marketable after 5 months storage†	72.00 ±2.501	66.00 ±2.501	96.00 ±2.501	84.00 ±2.501	81.00 ±2.50

*Critical difference P = 0.05 = 1.14 tons per acre.
†Critical difference P = 0.05 = 7.51 per cent.

TABLE V—The Effect of Boron, Copper, Manganese, and Zinc on Turnips Grown on a Clay Soil

	Soil Treatments				
	Control	Boron	Copper	Manganese	Zinc
Total yield roots (tons per acre)*	18.32 ±0.324	17.54 ±0.324	17.60 ±0.324	19.87 ±0.324	19.33 ±0.324
Average weight roots (pounds)	1.558	1.32	1.38	1.60	1.323
Total carbohydrate (per cent fresh weight)	7.30	9.07	7.33	7.20	8.00
Percentage marketable after 5 months storage†	40.00 ±3.52	80.00 ±3.52	55.00 ±3.52	68.00 ±3.52	95.00 ±3.52

*Critical difference P = 0.05 = 0.994 tons per acre.
†Critical difference P = yield 10.23 per cent.

increase shown by those from the copper treated plots is not statistically significant.

A significant increase in yield of carrots was obtained in the clay

TABLE VI—THE EFFECT OF BORON, COPPER, MANGANESE, AND ZINC ON TURNIPS GROWN ON A SANDY LOAM

	Soil Treatments				
	Control	Boron	Copper	Manganese	Zinc
Total yield roots (tons per acre)*	14.20 ±0.663	12.42 ±0.663	11.52 ±0.663	12.36 ±0.663	12.20 ±0.663
Average weight of roots (pounds)	1.30	1.165	1.07	1.15	1.13
Total carbohydrate (per cent fresh weight)	10.80	11.24	10.20	10.96	10.60
Percentage marketable after 5 months storage†	78.00 ±3.732	75.00 ±3.732	76.00 ±3.732	68.00 ±3.732	76.00 ±3.732

*Critical difference P = 0.05 = 1.906 tons per acre.
†Critical difference P = 0.05 = 11.04 per cent.

TABLE VII—THE EFFECT OF TREATMENTS ON YIELD, SUGAR CONTENT AND STORAGE QUALITY OF CARROTS GROWN IN THREE DIFFERENT SOIL TYPES*

Treatment	Yield			Total Sugars			Storage Quality		
	Peat	Clay	Sand	Peat	Clay	Sand	Peat	Clay	Sand
Boron	+	0	+	−	+	−	+	+†	−
Copper	+	+†	+	−	−	−	0	+†	+†
Manganese	0	0	+†	−	−	−	+	−	+
Zinc	+†	0	+	0	+	0	+	+	+

*+ = A significant increase (5 per cent level).
†+ = A highly significant increase (1 per cent level).
0 = A non-significant increase or decrease.
− = A significant decrease.

TABLE VIII—THE EFFECT OF TREATMENTS ON YIELD, TOTAL CARBOHYDRATE AND STORAGE QUALITY OF TURNIPS GROWN IN TWO DIFFERENT SOIL TYPES*

Treatment	Yield		Total Carbohydrate		Storage Quality	
	Clay	Sand	Clay	Sand	Clay	Sand
Boron	−	−	+†	+	+†	0
Copper	−	−	0	0	+	0
Manganese	+	−	0	0	+	0
Zinc	+	−	+	0	+†	0

*+ = A significant increase (5 per cent level).
†+ = A highly significant increase (1 per cent level).
0 = A non-significant increase or decrease.
− = A significant decrease.

soil only by the application of copper. The root was increased in relation to top by all treatments but notably by the boron. The sugar content was increased by boron and zinc. Keeping quality was increased by boron and copper and, to a lesser extent, by zinc.

In the light sandy loam the total yield was increased by all the micro-elements applied. Copper and manganese increased roots in relation to tops. The sugars were not enhanced by any of the treatments. Storage life was increased by copper, manganese and zinc.

Turnips:—The total yield of turnips was increased by the application of manganese and zinc but depressed by boron and copper.

The total carbohydrate content was increased by boron and zinc. The keeping quality was increased by all treatments but notably by boron and zinc.

None of the micro-elements used on the light sandy soil increased the total yield of turnips, in fact they tended to depress it. There was a tendency for boron to increase total carbohydrate. Similarly with keeping quality, it was not enhanced by any of the treatments in this soil type.

The above data showing the effect of applications of boron, copper, manganese and zinc on yield, carbohydrate and keeping quality of carrots and turnips grown on different soil types are summarized in Tables VII and VIII.

Discussion of Results

Soil Type Yield:—The difference in yield on the various soil types is pronounced. This difference does not seem to be closely correlated with soil reaction or nutrient supply. Physical structure, aeration organic matter, and water relationships are involved. The micro-elements also give different responses in different soil types, moreover, the responses of carrots was not always the same as that of turnips. In the peat soil an increased yield of carrots was obtained by all treatments. This increased yield was accompanied by a decrease in sugar content and dry weight. In clay an increase in yield was obtained by copper only which was accompanied by a decrease in sugar content. In sandy loam all treatments increased yield and decreased sugars although dry weight was variable.

In the peaty soil and sandy loam low sugar content in carrots was associated with high keeping quality while in the clay soil there was a tendency for the reverse to be true. Turnips which were grown in the clay soil had a high carbohydrate content whenever they had a high keeping quality, on the other hand, those grown in the sandy loam had a carbohydrate—storage relationship only in that neither was affected by the treatments.

Root-Top Relationship:—The marked difference in size of root in relation to top is worthy of note although it does not bear any consistent relationship to yield or storage quality. The peaty soil produced a top equal in weight to that of the roots of carrots, but not at the expense of the root, whereas the weight of top in the sandy loam was only one-third that of the root. That the micro-elements increased the root more than they did the top, especially in the peat and clay, is of interest.

Neither the control carrots or turnips showed any visible foliage symptoms of boron, copper, manganese or zinc deficiencies, as described by various workers (3, 4, 7), nor did they exhibit in the harvested roots, or develop in storage, any internal symptoms similar to those described as such deficiency troubles (2, 7). It is noteworthy that while these crops showed no visible signs of micro-element deficiencies, yet responses were obtained by their application as reflected by increased yield, changed sugar content and keeping qualities. It is true that these soils are subjected to heavy leaching (approximately

50 inches rainfall) which could cause border-line deficiencies of micro-elements even though the origin of the soil is such that they may not be expected (1).

CONCLUSIONS

In the Fraser Valley of British Columbia different soil types respond differently to applications of boron, copper, manganese and zinc. Different crops also show differences in their response to applications of those micro-elements.

There was no visible evidence of micro-element deficiencies in the carrots or turnips grown on these soils, nevertheless responses were obtained by their applications as reflected by increased yield, changed sugar content and storage values.

Applications of the micro-elements used increased root size in relation to top.

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Relation of Fertility Levels to Tenderness of Garden Beets

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THE mineral content of vegetables grown under known conditions of fertilizer treatment and on known soil types has been reported. (1, 3, 4). These investigations dealt with the mineral content as it affects the nutritive value but were not concerned with the cooking qualities of the vegetables. Blackmore *et al* have reported a study of the relation of fertility levels and temperature to the color and quality of garden beets grown on the Ohio State University fertilizer plots at Columbus, Ohio (2). It was shown by this study that the quality as to color and taste varied with the different fertilizer treatments.

For the study here reported, the object was to compare the relative tenderness of beets which had been grown to definite stages of maturity on plots of different levels of fertility, and which had been boiled for given lengths of time.

The relative tenderness of the cooked beets was judged by penetrometer tests: (a) of beets grown on different plots, gathered at one stage of maturity, and boiled for a given length of time; and (b) of beets grown on these plots, gathered at another stage of maturity and boiled for a different length of time.

The beets used were of the Detroit Dark Red variety and were grown during the season of 1942 on eight plots which differed as to fertilizer treatment. These plots were the same ones as those in the study reported by Blackmore (2), the same fertilizer treatment having been continued for an additional year after his study, making a total of 13 years. The types of fertilizer treatment are indicated in Tables I and II. One crop used in the present study was planted on April 1, 1942 and samples from this crop were tested during the first half of August. The other crop was planted on June 30, 1942 and samples from this crop were tested during the second half of August. Soil conditions and fertilizer treatments were the same for the two crops. The yields and soil fertility levels of the April first planting are given in Table I.

METHOD

Successively, each day on which tests were to be made, beets were harvested from one plot, delivered promptly to the laboratory and tested promptly after being received. The beets from each lot were divided into groups according to size by caliper measurement of diameter at right angles to the axis from root to stem. All beets 9 centimeters or more in diameter were classed as large, those from 7 to 8 centimeters as medium, and those from 5 to 6 centimeters as small. There were no large beets among those planted on June 30.

A slice 2 centimeters in thickness, cut perpendicular to the axis, was removed from the midsection of each beet. Slices were placed in a single layer in a 3-quart aluminum pan containing 6 cups of boiling

TABLE I—BEET YIELDS OF EIGHT PLOTS (EACH PLOT CONSISTED OF ONE ROW 65 FEET IN LENGTH; SEED WAS SOWN ON APRIL 1 AND BEETS WERE HARVESTED JULY 14 AND 15; YIELDS ARE THE AVERAGE FOR THREE PLOTS EXCEPT AS NOTED)

Treatment	Beet Yields (1942)		
	No. of Beets	Weight of Roots (Lbs)	Weight of Tops (Lbs)
No fertilizer	145	49.8	18.4
No nitrogen	179*	50.5*	21.0*
No phosphorus	186	72.8	26.8
No potassium	229*	82.4*	35.0*
Complete fertilizer	232	83.4	32.0
Double nitrogen	217	94.3	39.8
Double phosphorus	207*	89.1*	29.2*
Double potassium	205	83.2	33.1

*Average of two plots only.

water, covered, and boiled gently. The approximate length of the cooking period to be allowed for beets from each of the two plantings was determined by preliminary tests. For the beets planted April first the cooking period was 40 minutes; for those planted June 30, the period was only 20 minutes. These cooking periods were found to give a product that was tender in each case but not cooked to a degree of doneness that would allow the needle of the penetrometer to penetrate the slice completely. The cooked slices were allowed to cool on a wire rack for 10 minutes. At the end of that period penetrometer tests were made, 10 readings being taken in the most prominent ring of each slice. Five beets were tested in each size group. The average score of penetrometer readings for beets from each plot of the crop planted April first was determined by combining the 150 readings; for beets from each plot of the crop planted June 30 by combining the 100 readings (Table II).

RESULTS

I. Crop Planted April 1:—The penetrometer values given in Table II increase in proportion to the tenderness of the beets. As indicated

TABLE II—AVERAGES OF PENETROMETER READINGS OF BEETS GROWN ON 8 PLOTS WITH DIFFERENT FERTILIZER TREATMENTS

Treatment	Seed Planted April 1, 1942 and Beets Tested After Boiling 40 Minutes				Seed Planted June 30, 1942 and Beets Tested After Boiling 20 Minutes		
	Average Score for:				Average Score for:		
	Large Beets	Medium Beets	Small Beets	All Sizes	Medium Beets	Small Beets	All Sizes
No fertilizer	89	43	62	65	89	77	83
No nitrogen	61	61	27	50	91	41	66
No phosphorus	99	66	66	77	104	105	104
No potassium	76	43	32	50	78	91	84
Complete fertilizer	119	107	78	101	126	118	122
Double nitrogen	77	52	90	73	88	80	84
Double phosphorus	80	48	32	53	80	61	70
Double potassium	67	59	63	63	122	82	102
Average for all treatments	83	60	56	66	97	82	90

in Table II, beets from the plot that received complete fertilizer treatment were more tender than those from any of the other plots. Beets from plots lacking nitrogen and potassium were least tender of all. Blackmore (2) found that the crude fiber content of the 1941 crop was highest in beets from the minus potassium plot and was high also in beets from the plots receiving double phosphorus and complete fertilizer. For beets grown on corresponding plots in 1942 the average scores of penetrometer readings were as follows: for the minus potassium plot, 50; for the double phosphorus plot, 53; for the complete fertilizer plot, 101. Thus two of the three plots which had produced beets of high crude fiber in 1941, produced beets of low penetrometer readings in 1942.

Among beets of the same maturity the average penetrometer score indicated that large beets were more tender than medium sized or small ones in all cases except the beets from the plot receiving double nitrogen. It would seem that size may be related to growing conditions, and that larger beets are produced under more favorable conditions.

An analysis of variance (5) was made to determine the effect of fertilizer treatments upon the variance among the average scores for beets from the eight plots. For the beets from plots receiving different fertilizer treatments the mean square of variance was 4544; for beets from plots receiving the same fertilizer treatment it was 1369. These two mean squares were shown to be significantly different ($F = 3.32$) which indicates that the fertilizer treatments were a significant factor in variance among average scores. The mean difference between the scores for the beets from the plot receiving complete fertilizer and those from the plot lacking in nitrogen was significant (m 51, s 39.3 and $P. < .01$).

II. Crop Planted June 30:—Beets from this crop had matured to a marketable size but none had grown to be 9 or more centimeters in diameter. The cooking time for beets of this crop had to be limited to 20 minutes as compared to 40 minutes for the crop planted April first. Among beets of the crop planted June 30 the ones classed as medium sized were slightly more tender in six cases out of eight than were the small ones.

The beets from the plot that received the complete fertilizer treatment were more tender than those from any of the other plots. Beets produced on plots lacking in nitrogen were the least tender of all those tested. The difference between the average penetrometer scores for the beets from these two plots was significant ($P = < .01$).

SUMMARY AND CONCLUSIONS

Penetrometer readings were made on cooked slices of beets grown on plots differently fertilized and of beets of varying stages of maturity to determine relative tenderness.

Indications from this study are that the kind and amount of fertilizer in the soil and the size and maturity of beets are factors related to tenderness of beets when boiled. The plot receiving complete fertilizer yielded beets that were more tender than those grown on plots containing an excess of one nutrient or on those lacking necessary nutrients. Among beets of the same maturity large ones were more tender than smaller ones.

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Effect of Stage of Fruit Maturity at Time of Harvest and Method of Drying on the Germination of Pimiento Seed[1]

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PEPPER growers who raise their own plants are well aware of the fact that in many instances poor stands result even when all seemingly known precautions in planting are taken. Results of work reported by Barton (1) show that the storage temperature to which pepper seed is exposed previous to planting greatly influences germination. Kotowski (5) reported results of studies of the effect of temperature on the germination of pepper seed. In general, the speed of germination increased as the temperature was increased from 18 degrees to 30 degrees C. No germination took place at 11 degrees C. Cochran (2) studied the effects of temperature and methods of watering on the germination of pepper seed. Results of this work confirmed those previously reported by Kotowski in that there was an increase in speed of germination with a corresponding increase in temperature. The data also reveal that under the conditions of the experiment watering by sub-irrigation, that is, by holding the seed flats in an inch of water in a large galvanized tank until the soil surface became damp, definitely reduced the germination of the seed under five different temperature conditions. This decrease was believed to have resulted from a lowering of the soil temperature since a great deal of cold tap water was absorbed by the soil each time the flats were watered in this manner. It is not likely that the reduction in germination resulted from an insufficient oxygen supply because the soil was light in texture and well drained which should have allowed for adequate gas exchange. Cochran (3) found that the germination of pimiento seed taken from fruits that had either been roasted or scalded to remove the skins for canning was reduced to the point where the seed were unfit for planting.

During the last week or so of the pimiento season each year there are growers who deliver fruit to the canneries that is not fully ripe. In some cases the seed from such fruits is saved for planting. It was thought that such seed might possibly account for some of the poor germination often encountered in the hotbed. The question immediately arises, therefore, as to how immature can pimiento fruits be at harvest and yet contain seed that germinates well.

Since the bulk of the pimiento seed saved for planting purposes is dried in direct sunlight at temperatures of 90 degrees F or above, it was thought that this also might be a factor contributing to poor germination.

MATERIALS AND METHODS

All seed used in the tests, except in the check treatments, was collected from fruits which had been previously tagged on the date of flower anthesis. Except where otherwise noted the seed was planted within an hour after removal from the fruits. All treatments consisted of five replications of 200 seed each. The seed was sown ½ inch deep in flats filled with a well composted soil such as that which is ordinarily used by growers in the hotbed. The temperature of the greenhouse was maintained between 70 and 80 degrees F and the flats were kept sufficiently watered to insure maximum germination. The relative humidity of the greenhouse was not determined but the atmosphere was kept sufficiently moist to assure good growth by wetting down the dirt floor. After the seed began to emerge, the flats were examined daily to make notes and seedling counts. The last counts were made 30 days after the seed in each treatment had been planted.

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[1] Published with the permission of the Director as Journal Series Paper No. 114 of the Georgia Agricultural Experiment Station.

Experimental Results

In studying the effect of the stage of fruit maturity at the time of harvest on the subsequent germination of the seed, pimiento fruits were harvested at 10-day intervals from 20 to 60 days from the date of flower anthesis. The results of these tests are presened in Table I.

TABLE I—Effect of the Stage of Fruit Maturity on the Germination of Pimiento Seed

Age of Fruits From Date of Flower Anthesis (Days)	Stage of Fruit Maturity When Seed Removed	Average Germination (Per Cent)
20	Immature green	1.1
30	Mature green	6.1
40	Red and green streaked	68.5
50	Bright red	95.9
60	Dark red and shriveled	96.0
Dry seed (60 days from harvest) check	Bright red	91.1

It is noted from the above data that with an increase in maturity of the fruit through the 50-day-old or bright red stage, there was an increase in the percentage germination of the seed. Only 1.1 per cent of the seed germinated when taken from the 20-day-old (immature green) fruits, whereas 95.9 per cent germinated when taken from fruits of the 50-day-old (bright red) stage. Beyond this stage of maturity, however, an additional 10 days in the age of the fruit resulted in essentially no increase in germination.

Seed taken from the 20-(immature green) and 30-(mature green) day-old fruits were soft and turned brown when exposed to the air. This indicated that the extremely low germination of the seed was due to a lack of maturity. Cochran (4) found that under greenhouse conditions the embryo did not become fully mature until about 40 days after pollination.

From the results of these tests the most favorable time to harvest fruits for seed that germinates well, appears to be between the 50- and 60-day old stages, or at a time when the fruits have attained a bright to deep red color.

Under average hotbed conditions pepper seed is slow to germinate. The time required usually varies from 7 to 21 days, depending on the temperature and moisture of the soil and on the depth of planting.

Some authorities have believed that pepepr seed has a period of dormancy; however, the author has found this to be untrue. The seed will germinate immediately after maturity provided the environmental conditions are satisfactory. Not only is this true of mature, freshly harvested seed, but the data in Table I indicate that as good or even better germination may be expected from fresh seed than from seed that has been dried for some time.

EFFECT OF METHOD OF MATURING PIMIENTO SEED ON ITS SUBSEQUENT GERMINATION

In light of the results already presented in this paper it appears that the stage of fruit maturity is a safe criterion for selecting pimiento seed of high germination.

Fruits of the 30-(mature green) and 40-(red and green streaked) day-old stages are usually rather plentiful in pimiento fields at the time of the first killing frost. As a rule however, such fruits are of no commercial value because they do not possess the necessary red color for canning and are too immature from which to save seed. The question therefore arises as to whether or not the seed of such fruits might not in some way be induced to mature so they could be used for seed stock by the grower or sold for cash.

In this work 30 fruits each of the 30- and 40-day-old stages were selected at random from the field on September 2. Seed were taken from 10 fruits of each lot and planted in flats as previously outlined. Seed from 10 other fruits of each lot were removed and stored in envelopes for 30 days at room temperature. The remaining 10 fruits of each lot were placed in kraft paper bags and also stored for 30 days at room temperature. By the end of the storage period the fruits of both lots were dark red in color and somewhat shriveled. The seed was removed on October 2 and together with that removed earlier and stored in envelopes was planted on this date. The results of these tests are shown in Table II.

Attention is called to the fact that removing seed from either the 30-day-old (mature green) or 40-day-old (red and green streaked) fruits and storing them at room temperature for 30 days resulted in no increase in germination over that of seed removed from like fruits and planted immediately. As a matter of fact the storage treatment, perhaps due to the drying effect, resulted in a small decrease in germi-

TABLE II—EFFECT OF METHOD OF MATURING PIMIENTO SEED ON ITS SUBSEQUENT GERMINATION

Treatment	Average Germination (Per Cent)
Seed removed from 30-day-old (mature green) fruits and planted immediately	5.9
Seed removed from 30-day-old (mature green) fruits and stored for 30 days at room temperature	5.3
30-day-old (mature green) fruits stored for 30 days at room temperature	94.9
Seed removed from 40-day-old (red and green streaked) fruits and planted immediately	65.0
Seed removed from 40-day-old (red and green streaked) fruits and stored for 30 days at room temperature	64.4
40-day-old (red and green streaked) fruits stored for 30 days at room temperature	96.1
Dry seed (60 days from harvest) check	92.0

nation. On the other hand, when some of the same fruits were stored at room temperature for 30 days, after which the seed was removed and planted at once, germination was increased from 5.9 to 94.9 per cent in the case of the 30-day-old (mature green) fruits and from 65.0 to 96.1 per cent for the 40-day-old (red and green streaked) lot. These data, as well as examinations made of the seed, indicate that with an increase in fruit maturity in storage, there was an increase in the maturity of the seed as well. In other words, the fairly immature seed in such fruits was able to continue development by drawing on the food reserves within the fruits themselves even though they had been severed from the plants for a month.

It is evident from these results that pimiento growers may harvest mature green and red and green streaked fruits before frost, store them at room temperature for 30 days, and expect a high percentage of seed to germinate.

Effect of Drying of Seed on Germination

It is well known that most seed when stored for any great length of time under high or even medium temperature conditions germinates very poorly. With this fact in mind five lots of pimiento seed were removed from 50-day-old (bright red) fruits and one lot was planted immediately. Other lots were dried for 1, 2, 3, and 7 days in shade, in direct sunshine, and in the greenhouse after which samples of each were planted. The results of this experiment are shown in Table III.

TABLE III—Germination of Pimiento Seed as Affected by Method and Duration of Drying

Treatment of Seed	Seed Exposed to Drying Treatment (Days)	Average Germination (Per Cent)
Planted immediately	—	95.2
Dried in shade at average temperature of 72 degrees F	1	94.5
	2	94.1
	3	93.3
	7	93.5
Dried in direct sunshine at average temperature of 90 degrees F	1	94.3
	2	92.1
	3	93.6
	7	92.5
Dried in greenhouse at average temperature of 99 degrees F	1	94.2
	2	94.3
	3	92.9
	7	93.4
Dried for 2 days in sunshine then stored for 90 days at room temperature (check)	—	88.5

The higher germination of freshly harvested seed, when compared with seed dried for 1, 2, 3, and 7 days, was small yet consistent under all treatments. These small differences, however, would probably be of little economic importance to the grower and canner since in every case the percentage germination was high enough so that if the normal rate of seeding was followed good stands of plants could be expected in the hotbed.

The data indicate, therefore, that sun drying of pimiento seed for 1 or 2 days, the usual practice of the pimiento canners in Georgia, does not decrease germination enough to result in poor stands of plants.

The data under the check treatment in Table III suggest that under the conditions of these experiments humidity rather than temperature appears to be the influential factor causing the reduction in germination.

SUMMARY

Pimiento fruits were harvested at 10-day intervals from 20 to 60 days after the date of flower anthesis and the seed planted immediately in flats in the greenhouse.

Practically none of the seed from the 20-day-old (immature green) fruits germinated but with an increase in fruit maturity through the 50-day-old or bright red stage there was an increase in the percentage germination. Beyond this stage of maturity, however, an additional 10 days in the age of the fruits resulted in no increase in germination.

Storing immature seed of 30- and 40-day-old fruits for 30 days at room temperature resulted in no increase in germination when compared with that of seed that was removed from like fruits and planted immediately. On the other hand, storing fruits of both lots for 30 days at room temperature allowed the seed to mature to where 94.9 per cent of them from the 30-day-old (mature green) fruits and 96.1 per cent of them from the 40-day-old (red and green streaked) fruits germinated when planted in flats in the greenhouse.

Drying freshly harvested mature seed for 1, 2, 3, and 7 days under shade, in direct sunshine, and in the greenhouse resulted in no appreciable reduction in germination when compared with seed that was planted immediately after removal from the fruits.

CONCLUSIONS

The studies reported in this paper seem to warrant the following conclusions:

1. The most favorable time to harvest pimiento fruits for saving seed appears to be between the 50- and 60-day-old stages or at a time when the fruits have attained a bright to deep red color.
2. Pimiento growers may harvest 30-day-old (mature green) or 40-day-old (red and green streaked) fruits before frost, spread them out at room temperature for 30 days so as to allow them to ripen, and expect a high percentage of the seed to germinate.
3. The sun drying of pimiento seed for 1 or 2 days, the usual practice of the pimiento canners and growers in Georgia, does not decrease the germination enough to result in poor stands of plants in the hotbed.

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pH of Extracted Cell Sap and Phosphorus Content of Young Tomato Plants Growing on Varying Levels of Phosphorus[1]

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MUCH work has been done in the field of mineral nutrition on the relation of phosphorus in plants to its external manifestations and, to a more limited extent, to the internal behavior. The experiments described in this paper were designed to determine the pH of extracted cell sap and phosphorus content of young tomato plants growing on varying levels of phosphorus. Tidmore (5) and Parker and Pierre (4) found that such plants as corn, tomato and sorghum were able to make fair growth on relatively small amounts of phosphorus, 0.5 to 0.1 parts per million, provided that large volumes of solution were used and the phosphorus levels were rigidly maintained. Many nutrient solution formulae require 30 to 60 parts per million of phosphorus. Tidmore (5), Lyness (3) with corn, Cullinan and Batjer (2) with peach and apple trees report that the rate of phosphorus absorption was not directly proportional to the phosphate concentration of the culture solution. However, the amount of phosphorus found in the leaves or in the entire plant showed a close correlation with the supply of phosphorus in the nutrient solution. Lyness further reports that corn plants low in phosphorus have a high acidity under normal conditions, while with high concentrations the pH was near the average for plants making vigorous growth. The curve of the pH of the soil solution fitted rather well that for the pH of the sap from the vascular regions in the leaf.

METHODS AND RESULTS

Seeds of the Indiana Baltimore variety of tomato were sown in quartz sand that had been previously washed in dilute HCl. On February 1, 1943 the small seedlings which just showed their first true leaves, were transplanted, five per crock, into 2-gallon glazed crocks containing quartz sand. The plants were watered each day with a modified Purdue 2D (6) solution plus a minor element supplement containing Fe, Cu, Zn, and Mn with varying levels of phosphorus as found in Table I. The Purdue 2D solution was modified by substituting potassium phosphate for the calcium phosphate because of the relative insolubility of the latter.

TABLE I—MODIFIED PURDUE 2D NUTRIENT SOLUTION

Salt	mM Concentration	Elements (Ppm)
$MgSO_4$	0.5	12 Mg
KNO_3	10.0	390 K, 140 N
$(NH_4)_2SO_4$	1.0	36 NH_4 (28N)
$CaSO_4$	4.0	40 Ca
KH_2PO_4	1.0 (variable)	39 K, 32 P

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[1] Appreciation is due Dr. R. E. Girton of the Purdue Biology Department for his suggestions and criticism during the progress of this work.

The following concentrations of phosphorus were used: 1, 3, 6, 9, 15, 30 and 60 parts per million. A total of 21 crocks was used, making three replicates of each concentration. The solution was adjusted to a pH of 6.0. The greenhouse was maintained at 55 to 60 degrees F at night and 65 to 70 degrees F during the day.

Fifty days after transplanting, four plants from each crock were harvested. Height and fresh weight of tops and roots were obtained on all plants. Two plants from each crock were immediately frozen to save them for the pH determinations of the cell sap and the other two plants from each crock were dried in the oven for 18 hours at 80 degrees C prior to ashing for phosphorus determinations. The dry and fresh weight values are found in Table II.

TABLE II—FRESH AND DRY WEIGHT DATA OF YOUNG TOMATO PLANTS (TRANSPLANTED FEBRUARY 1, 1943, HARVESTED MARCH 20, 1943)

Conc. of P (Ppm)	Number Plants	Mean Height* (Cm)	Standard Deviation (Cm)	Average Fresh Weight (Gm)		Number Plants	Average Dry Weight (Gm)	
				Tops	Roots		Tops	Roots
1	12	13.3	3.04	7.2	1.6	6	0.59	0.11
3	12	24.4	4.21	19.3	5.8	6	2.28	0.33
6	11	35.0	3.84	31.5	5.8	6	2.26	0.34
9	12	39.5	4.50	38.8	7.0	6	3.00	0.39
15	12	40.5	3.40	46.9	8.1	6	3.75	0.44
30	12	36.3	2.82	37.2	6.0	6	3.06	0.37
60	12	41.7	3.40	42.7	6.7	6	3.13	0.38

*A difference of 4.97 centimeters is significant at the 5 per cent level.

The pH determinations were made on expressed cell sap. While the plants were still in the frozen state they were run through a food chopper, placed in a muslin bag and expressed under 5000 pounds pressure. The cell sap was then placed in a Beckman pH meter to determine the pH. In a preliminary trial the stems were separated from the leaves and leaf petioles and it was found that the stems were a little over 0.1 of a pH more acid than the leaves. In the final analysis the leaves and stems were mixed together for the pH determinations which are given in Table III.

TABLE III—pH OF EXPRESSED CELL SAP OF YOUNG TOMATO PLANTS

Concentration of P (Ppm)	pH	Concentration of P (Ppm)	pH
1	5.98	15	5.89
3	5.90	30	5.90
6	5.80	60	5.87
9	6.05	—	—

The phosphorus content of the plants was determined separately for the stems and leaves including petioles, by the Bell-Doisy-Briggs method (1). The results are found in Table IV.

DISCUSSION OF RESULTS

The plants receiving 1, 3 and 6 parts per million of phosphorus have, since the beginning, shown noticeable phosphorus deficiency symptoms.

TABLE IV—PHOSPHORUS ANALYSIS OF YOUNG TOMATO PLANTS

Concentration of P (Ppm)	Per Cent of P*		Concentration of P (Ppm)	Per Cent of P*	
	Leaves	Stems		Leaves	Stems
1	0.238	†	15	0.450	0.412
3	0.260	0.200	30	0.628	0.466
6	0.354	0.246	60	0.724	0.546
9	0.420	0.302	—	—	—

*On dry-weight basis.
†Leaves and stems combined.

They were stunted, purplish-green in color, and hard. The plants receiving 9 parts per million of phosphorus began to approach a more normal appearance and it was difficult to differentiate between it and the higher phosphate plants. The results in Table II show that the plants receiving 15 parts per million of phosphorus were second in height but first in fresh and dry weight. This would indicate that these plants received sufficient phosphorus and are closely approached by those receiving just 9 parts per million. Evidentally from 10 to 12 parts per million of phosphorus were sufficient for normal growth. These figures are very comparable with those of Cullinan and Batjer (2). They found that peach trees made greatest total weight on 10 parts per million of phosphorus as compared with those receiving 20 and 40 parts per million. The 10 parts per million series was second to the 40 parts per million plants in average total length of growth. In apples the 10 parts per million phosphorus series produced the greatest total linear growth and placed second in green weight of tops as compared with those receiving 20, 40, and 93 parts per million of phosphorus.

The principal acids which are components of plant buffer systems are carbonic, phosphoric, citric, malic, tartaric and oxalic. Plants that receive only a small amount of phosphorus might have a different pH of the cell sap: however, the results in Table III clearly show that varying levels of phosphorus have no significant effect where the pH of the nutrient solution is kept constant.

The results of Table IV show a high degree of correlation between the amount of phosphorus found in the plant with the supply in the nutrient solution; furthermore, the stems contain less phosphorus than the leaves. The results agree with those previously mentioned by Lyness (3) and Cullinan and Batjer (2).

CONCLUSIONS

1. Tomato plants in sand culture need only 15 parts per million or less of phosphorus in the nutrient solution for optimum growth.
2. The pH of the cell sap of young tomato plants was 5.8 to 6.0 when the pH of the nutrient solution is constant at 6.0 even though the phosphorus level is varied from 1 to 60 parts per million.
3. The pH of the cell sap of the stems was more acid than that of the leaves and petioles.
4. In young tomato plants the rate of phosphorus absorption is not directly proportional to the phosphate concentration of the nutrient

solution; however, the amount of phosphorus found in the leaves and stems closely correlates with the supply of phosphorus in the nutrient solution.

5. The leaves contain more phosphorus than the stems regardless of the amount of phosphorus in the nutrient solution.

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Yields of Hardy Snap Bean Strains

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IN 1936 a program of breeding hardy, productive, high-quality snap beans for southern United States was undertaken at the United States Regional Vegetable Breeding Laboratory at Charleston, South Carolina. Hardy strains have been developed which will give fair yields during periods of adverse weather when ordinary commercial varieties produce very low yields. This publication deals with yields of the hardy strains in comparison with commercial varieties when planted for summer and for normal fall and spring production.

MATERIALS AND METHODS

In 1937 certain hybrid strains involving crosses of material closely related to U. S. No. 5 Refugee with Stringless Black Valentine, Bountiful, and Brittle Wax were planted late in the season for a test of hardiness. Some of these appeared promising despite the weather which was very unfavorable for the varieties commonly grown in this area. These hybrid strains have been selected for satisfactory pod and bush types and what remains today appears to represent decided improvements in type over the heterozygous group which was used in 1937.

In 1940, 46 strains derived from these crosses were released to the 13 collaborating Southeastern State Agricultural Experiment Stations for trial. Some of these strains as released were quite uniform, while others were segregating for various characteristics. While they were being grown by the collaborators they were also being grown at Charleston for observation on seed yields, snap bean yields, ascorbic acid content, tolerance to adverse weather conditions, and other characteristics. The original stocks for distribution were finally selected on the basis of having given a better yield than Bountiful during the adverse bean season of the fall of 1939, when Bountiful was the only shipping variety that gave even a fairly satisfactory yield.

The strains released for trial and further selection were especially developed to produce during the summer months when bush snap beans are ordinarily not grown in the local area. However, if grown and tested during such weather, commercial varieties could not be used for checks on yield since they are almost certain to produce near crop failures (Table I). The results reported in Tables II and III are for spring and fall plantings of 1940 and 1941 in which the commercial varieties could be used for comparison.

The strains were arranged in a 7 x 7 lattice square (1) with 4 series (replicates). The strains were numbered for convenience from 1 to 49, with 9, 48, and 49 representing the commercial varieties Brittle Wax, Bountiful, and Stringless Black Valentine, respectively. Plots were single rows 3 feet apart and 32 feet long. Local-grown seed of the strains originated by the United States Regional Vegetable Breeding Laboratory was used throughout the experiment, but western-

TABLE I—EFFECT OF DATE OF PLANTING ON SUMMER YIELDS OF THREE COMMERCIAL SNAP BEAN VARIETIES IN COMPARISON WITH STRAINS FROM WHICH VARIETAL INTRODUCTIONS HAVE BEEN MADE SUBSEQUENT TO THESE TESTS, CHARLESTON, S. C. (YIELDS IN POUNDS PER ACRE ARE AVERAGES OF FOUR PLOTS GROWN IN 1937)

Variety	First Picking June 19 (Pounds)	Second Picking June 23 (Pounds)	Third Picking June 25 (Pounds)	Fourth Picking July 2 (Pounds)	Total Yield (Pounds)
Early Summer Planting, May 7, 1937					
Stringless Black Valentine	121	53	31	5	210
Bountiful	432	121	25	15	593
Brittle Wax	57	90	19	2	168
Cooper Wax*	824	925	600	310	2,659
Ashley Wax* and Florida White Wax*	1,137	1,924	783	410	4,254
Florida Belle*	1,434	1,783	944	375	4,536
Logan*	1,510	2,053	847	595	5,005
VBL 46*	1,711	1,995	1,024	298	5,028

Late Summer Planting, June 21, 1937

Variety	First Picking July 30 (Pounds)	Second Picking Aug 5 (Pounds)	Third Picking Aug 10 (Pounds)	Fourth Picking Aug 16 (Pounds)	Total Yield (Pounds)
Stringless Black Valentine	7	5	2	0	14
Bountiful	18	3	0	1	22
Brittle Wax	5	5	2	3	15
Cooper Wax*	327	483	295	578	1,683
Ashley Wax* and Florida White Wax*	723	495	1,024	273	2,515
Florida Belle*	985	856	975	683	3,499
Logan*	884	963	1,025	567	3,439
VBL 46*	1,095	766	1,124	497	3,482

*The strain under test in 1937 was the ancestor of the indicated variety which was named and subsequently introduced.

TABLE II—CHARACTERISTICS AND BEHAVIOR OF CERTAIN STRAINS AND VARIETIES OF SNAP BEANS INCLUDED IN TESTS OF FORTY-NINE STRAINS GROWN IN LATTICE SQUARES, CHARLESTON, S. C. (AVERAGE OF FOUR PLOTS FOR EACH ENTRY IN EACH COLUMN)

Hybrid Line or Variety	Description of Pods	Spring 1940			Spring 1941	
		Height of Plant (Inches)	Leaves Per Plant	Live Leaves Per Plant	Leaves Per Plant	Live Leaves Per Plant
VBL 8, Cooper Wax	Long, round wax	14.3	30.0	17.5	31.7	18.9
Brittle Wax	Long, round, curved wax	14.9	25.7	18.1	24.2	16.0
VBL 19, Ashley Wax	U. S. 5 Refugee wax type, medium long, round	12.6	29.5	18.2	29.8	19.0
VBL 21*	Medium long, round wax	13.4	27.2	17.7	27.5	17.7
VBL 28†	Long, dark green, nearly round	14.9	19.6	11.5	19.1	10.8
VBL 30	Long, dark green, oval-round	14.8	25.1	17.0	23.2	15.8
VBL 39	Medium long, dark green, oval-round	12.9	22.7	10.4	21.6	8.2
VBL 40	Medium long, dark green, oval-round	13.4	27.1	14.8	26.6	13.6
VBL 41‡	Medium long, dark green, oval-round	12.7	22.0	11.2	23.6	12.5
VBL 43	Medium long, dark green, oval-round	12.4	27.2	15.6	28.8	17.5
VBL 46	Long, light green, flat	13.9	26.0	19.7	25.0	18.2
Bountiful	Long, light green, flat	13.6	17.7	9.8	18.3	10.6
Stringless Black Valentine	Long, dark green, oval	16.3	16.1	7.9	18.8	10.8
Average of above 13 strains		13.9	24.3	14.5	24.5	14.6
Average of 49 strains		13.8	25.9	16.3	25.9	16.4
Significant difference		1.4	2.7	3.0	7.9	8.2

*Florida White Wax variety is derived from VBL 21.

†Florida Belle variety is derived from VBL 28.

‡Logan variety is derived from VBL 41.

grown seed of the commercial varieties was used. The rate of seeding was approximately 25 pounds per acre for the 46 VBL strains and somewhat heavier for the three commercial varieties. Seed was packaged to obtain about 75 seeds of each of the VBL strains for each row but about 100 seeds of the commercial varieties. This was in accordance with our previous findings that rates of seeding above 30 pounds per acre would depress the yields of the hybrid strains, and in accordance with the findings of other experimenters (2) that commercial shipping varieties in the South respond well to heavier rates of seeding. In nearly all cases good stands were obtained.

The 49 strains had all been observed previously to mature to a marketable stage within a few days of each other. Each strain was harvested as it matured with a total of four pickings for each plot for each planting, except that in the fall of 1940 five pickings were made from each plot. The snap beans were not graded and only total weight of pods harvested was recorded. With frequent and careful picking, under-mature and over-mature pods were mostly avoided.

Seed yields were obtained from separate plantings using the same plan of randomization and were always adjacent to the area used for snap bean yields. The ripe pods were removed from the plants, placed in netting bags, and artificially dried. After drying was complete, the bags were hand threshed, the seed exposed to drying room conditions of 50 per cent relative humidity or less for a period of 10 days, and then weighed. All weights were recorded in grams, since with the size of plot used the yield per plot in grams equals the yield per acre in pounds and conversion was not necessary.

Plant height was determined by placing a yardstick in the row with the bean plants at blooming time and observing the height to the

TABLE III—YIELD OF SHELLED, DRY SEED BEANS FOR CERTAIN STRAINS OF SNAP BEANS SELECTED FROM FORTY-NINE STRAINS GROWN IN LATTICE SQUARES, CHARLESTON, S. C., 1940 AND 1941 (MEAN OF FOUR PLOTS FOR EACH PLANTING YIELD)

Hybrid Line or Variety	Acre Yields				
	Spring 1940 (Pounds)	Fall 1940 (Pounds)	Spring 1941 (Pounds)	Fall 1941 (Pounds)	Average Four Plantings Mean of Sixteen Plots (Pounds)
VBL 8, Cooper Wax	952	226	256	126	390
Brittle Wax	98	321	466	298	296
VBL 19, Ashley Wax	1,010	764	503	240	629
VBL 21*	651	636	301	329	480
VBL 28†	1,005	885	588	481	740
VBL 30	874	974	649	573	767
VBL 39	1,061	854	518	604	759
VBL 40	1,065	837	524	544	743
VBL 41‡	897	726	457	618	674
VBL 43	1,123	991	704	578	849
VBL 46	677	823	757	747	751
Bountiful	587	784	664	643	669
Stringless Black Valentine	669	810	547	390	604
Average of above 13 strains	821	741	533	475	642
Average of 49 strains	703	681	502	426	578
Significant difference	511	256	206	256	168

*Florida White Wax variety is derived from VBL 21.
†Florida Belle variety is derived from VBL 28.
‡Logan variety is derived from VBL 41.

nearest quarter inch of leaves in a horizontal position. Three readings per row were made and the average was recorded as the plant height for that row. At the end of each spring picking season the number of leaves or leaf traces as well as the number of leaves still showing some normal green areas for the first 10 normal plants in each row was recorded. This latter figure designates live leaves per plant.

A brief description of 10 of the 46 hybrid strains and of the three commercial varieties included in the lattice square is given in Table II. The experimental results with these strains given in the same table help to characterize the various strains, but these will be discussed below under Results.

Yields of ascorbic acid per acre in 1941 are based on yields of snap beans per acre (Table IV) and determinations of ascorbic acid as given in a previous paper (4).

TABLE IV—Yield of Snap Beans for Certain Varieties, Charleston, S. C., 1940 and 1941, and Yield of Ascorbic Acid for Two Crops Grown in 1941 (These Are Selected From Forty-Nine Strains Grown in Lattice Squares — Mean of Four Plots for Each Planting Yield)

Hybrid Line or Variety	Acre Yields					
	Spring 1940 (Pounds)	Fall 1940 (Pounds)	Spring 1941 (Pounds)	Fall 1941 (Pounds)	Average Four Plantings Mean of Sixteen Plots (Pounds)	Ascorbic Acid§ (Grams)
VBL 8, Cooper Wax	5,358	5,960	2,842	2,525	4,186	270
Brittle Wax	3,444	5,454	3,609	3,069	3,894	358
VBL 19, Ashley Wax	5,132	9,199	4,416	4,845	5,898	478
VBL 21*	5,137	9,376	3,601	2,408	5,131	301
VBL 28†	6,221	9,993	4,305	4,261	6,195	478
VBL 30	6,065	9,573	4,110	4,951	6,175	427
VBL 39	6,787	9,795	4,220	4,076	6,220	431
VBL 40	5,608	8,055	3,742	5,110	5,629	443
VBL 41‡	6,469	9,829	4,018	5,016	6,333	498
VBL 43	6,618	8,381	4,272	3,549	5,705	378
VBL 46	4,233	8,934	5,057	4,938	5,791	620
Bountiful	5,377	8,738	3,979	5,087	5,795	563
Stringless Black Valentine	5,963	8,488	4,020	3,848	5,580	458
Average of above 13 strains	5,570	8,598	4,015	4,129	5,579	439
Average of 49 strains	5,310	8,122	3,800	3,857	5,272	381
Significant difference	1,038	1,757	758	1,035	866	139

*Florida White Wax variety is derived from VBL 21.
†Florida Belle variety is derived from VBL 28.
‡Logan variety is derived from VBL 41.
§Based on an average of 16 determinations for each strain for each of two crops.

Supplementary irrigation was necessary, two irrigations of about one acre inch each were applied to each crop.

RESULTS

The results in Table I for 1937 are typical of the inability of the commonly grown varieties to produce under summer conditions, but the yields from the hybrids are unusually high. Since then, limited tests have indicated that the hybrids can be depended upon for summer yields of 2000 to 3000 pounds per acre.

Compared to western seed yields, all seed yields (Table III) were low, with a general average of 578 pounds per acre for the 49 strains for the four crops. Of 49 strains in the test detailed results are given for only 10 hybrid strains and three commercial varieties in Table III. Twelve strains yielded significantly less seed than Stringless Black Valentine, and 17 significantly less than Bountiful. Fourteen strains yielded more than Bountiful but VBL 43 was the only one yielding significantly more. Twenty-four strains yielded more than Stringless Black Valentine (including Bountiful as one of the strains) but only one of these (VBL 43) yielded significantly more.

The four lattice squares for seed yields were combined in a single variance analysis without departing from a lattice square arrangement. When this was done the size of significant difference at 5 per cent level using residual as error was 168 pounds; but 187 pounds was required if varieties x season was used as the error item; and 169 pounds if varieties x year x season. Year, season, and varieties were all highly significant using as error either residual, or varieties x year x season, or varieties x season, in obtaining *F* values.

Yields of snap beans were good with a general average for the 49 strains of 5,272 pounds per acre for the four crops (Table IV). In Table IV the detailed data have been limited to 10 hybrid strains and three commercial varieties out of 49 in the test. Considering all 49 strains, 15 yielded significantly less than Bountiful and 7 significantly less than Stringless Black Valentine. Eight strains yielded more than Bountiful but none significantly more. Sixteen strains yielded more than Stringless Black Valentine but none significantly more.

The four lattice squares for snap bean yields were combined in a single variance analysis without departing from the lattice square arrangement. The size of a significant difference at 5 per cent level for varietal means of 16 determinations, using residual as error, was 866 pounds; with varieties x year x season as error, 973 pounds; with varieties x year, 1007 pounds; and with varieties x season, 1148 pounds. Using residual for comparison, year, season, varieties, varieties x season, and year x season all gave highly significant *F* values. Although the *F* value for varieties x season was highly significant, it was numerically only 1.69. The standard deviation derived from varieties x season is 1400 in comparison with 1078 for that from residual.

Yields of ascorbic acid (vitamin C) for the two crops grown in 1941 varied from 248 to 620 grams per acre, with a general average of 381 grams per acre (Table IV). Considering all 49 strains, 46 produced significantly less ascorbic acid than the highest yielding strain, VBL 46. Bountiful averaged 57 grams per acre less than VBL 46 but this difference was not significant.

Average height of plant is given in Table II for only 13 of the 49 strains tested. Forty-three strains had plants significantly shorter than Stringless Black Valentine. One strain averaged the same height as Stringless Black Valentine. Only two strains averaged significantly shorter than Bountiful.

In both spring crops Bountiful and Stringless Black Valentine averaged fewer leaves than any other strains tested but in several cases the differences were not significant. (Details are given for 13 lines in Table II). For leaves alive at the end of the picking seasons Bountiful and Stringless Black Valentine ranked low in both years; but in 1940 VBL 20 came through the season with fewer live leaves than either of these varieties, and in 1941 VBL 34 and VBL 39 had fewer. The VBL strains designated did not have significantly less than Bountiful or Stringless Black Valentine (Table II).

DISCUSSION

Since it was necessary to confine comparative tests of the 46 VBL strains with the three commercial varieties to the regular cropping season in order to avoid crop failures for the commercial varieties, much care is needed in interpreting the results. In the first place, if the VBL strains are hardy they should be able to make a good showing under handicaps. The first handicap imposed was the growing of all VBL strains from locally produced seed, while Brittle Wax, Bountiful, and Stringless Black Valentine were all grown from seed produced under western growing conditions. The three commercial varieties, if grown locally, will within a few generations fail to produce a satisfactory crop, while many VBL lines and related strains have been grown locally for more than ten generations without noticeable deterioration. During this growing the VBL lines have been exposed many times to blight epidemics and to rain or frost, or both, at harvest time.

The second handicap imposed was that of spacing of rows. The three commercial varieties average a greater plant height and spread than do the VBL lines. For instance, VBL 19 in other experiments has averaged very high yields when grown in rows 24 inches apart in comparison with Stringless Black Valentine which has not made satisfactory yields with this relatively closer row spacing. In a complex experiment of this type it was not feasible to have different row spacings for various strains, and a standard of 36 inches was adopted.

Many of the VBL lines could have been picked over a longer period of time in the case of the two spring crops, but this was not done in order to retain a fair basis of comparison with the commercial varieties. The ability of a variety to bear over a long period without being late in beginning production is probably of value to the home gardener and canner, especially during the war emergency, but is of no advantage to the average southern truck crop grower since he wishes to harvest his crop as quickly as possible with a minimum number of pickings.

Several of these VBL lines or selections from them have been released as named varieties. VBL 8 has been released as Cooper Wax; VBL 19, as Ashley Wax; and a selection from VBL 41, as Logan, a strain resembling the variety Tendergreen but more productive under conditions in the vicinity of Charleston. In cooperation with the Florida Agricultural Experiment Station, selections from VBL 21 and VBL 28 have been released as Florida White Wax and Florida Belle, respectively.

CONCLUSIONS

During the course of development of recently introduced bean varieties hardiness tests were made of the ability of these segregating strains to produce under summer conditions in the vicinity of Charleston, South Carolina, in 1937. The five hybrid strains gave satisfactory yields, but the yields of the three commercial varieties included for comparison approached crop failure.

Strains of snap beans developed at the United States Regional Vegetable Breeding Laboratory for hardiness under adverse weather conditions have yielded satisfactorily during the normal spring and fall seasons of 1940 and 1941. Seed yields have been low in comparison with western seed bean yields, but snap bean yields have been very satisfactory. Under these conditions the average yield of the hardy strains was not significantly different from the average yields of three commercial varieties. On the basis of specific comparisons significant differences were found in some cases.

The summer hardiness exhibited by these hybrid strains was introduced by the U. S. No. 5 Refugee or related parent (3). Some segregation for hardiness has been observed. The crops planted at some of the normal planting times were subject to rather difficult conditions, and the hybrid materials have thus undergone much natural selection.

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The Influence of "Crowded" Bedding of Roots on Plant Production of the Porto Rico Sweetpotato

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FROM 1939 to 1942 inclusive, the Agricultural Engineering and Horticultural Sections of the South Carolina Experiment Station have conducted cooperative investigations to determine the influence of certain environmental and cultural factors on the production of sweetpotato plants in electrically heated hotbeds. The factors studied were type of hotbed cover, low cost insulating materials, relatively high and low soil temperatures, various types of bedding media and "crowded" bedding of the roots. Of these factors the effect of "crowded" bedding of the roots was particularly striking. To bring the results on "crowded" bedding to the attention of sweetpotato specialists and others interested in sweetpotato production, the most pertinent data are presented herewith.

Materials and Methods

"Crowded" bedding consisted of placing 600 roots in 36 square feet of bedding space, and regular bedding consisted of placing 300 roots in an equal area. Thus, in "crowded" bedding approximately twice as many roots were bedded in any given area as is ordinarily practiced. Many roots were in contact with each other.

Roots of the Unit 1 strain of the Porto Rico were used. They were bedded during the last week of March or the first week of April. Bedding operations consisted of selecting and weighing roots of U. S. No. 1 and No. 2 grade, treating them with a 1–1000 solution of corrosive sublimate for 8 minutes, and bedding them about 1 inch below the surface of a 6-inch layer consisting of two parts of sand and one part loam. To control bed rot caused by *Sclerotium rolfsii,* hydrated lime was mixed with the bedding soil at the rate of 1.5 pounds per 18 square feet of bedding space.

The temperature of the soil and type of hotbed cover varied from year to year. In 1939 and 1940 the thermostats were set to shut off the electricity at 78 to 80 degrees F, and in 1941 and 1942 they were set to shut off the electricity at 83 to 85 degrees F. Sun-ray cloth, a glass substitute, was used in 1939, muslin was used in 1940, and muslin and Cal-Nitro sacks were used in 1941 and 1942. The first plants were pulled from 24 to 27 days after the roots were bedded, and pulling continued at intervals of 1 week until five pullings were made. Since growers are interested in early plant production, the data are presented separately for the first three pullings and for all five pullings.

Discussion of Results

The data, presented in Table I, show the effect of "crowded" bedding on plant production and electrical consumption. The figures show that "crowded" bedding markedly increased the number of plants per

TABLE I—INFLUENCE OF "CROWDED" BEDDING OF ROOTS ON PLANT PRODUCTION AND ELECTRICAL CONSUMPTION (1939, 1940, 1941, AND 1942)

Number of Roots Per Unit Area*	Total Number Plants Per Bed*	Mean Number Plants Per Root	Mean Weight Plants (Grams)	Plants Per 50 Pound Bushel	Total Kilowatt Hours Per Bed*	Total Kilowatt Hours Per 1000 Plants
		First Three Pullings				
600 (A)	7222	12.1	4.4	1726	151.3	20.1
300 (B)	4015	13.4	4.8	1883	138.5	35.6
Difference (A minus B)	3207	−1.3†	−0.4	−157†	12.8**	−15.5**
Difference Necessary for Significance. Odds 19:1		−2.06			3.48	−6.20
		All Pullings				
600 (A)	9545	15.9	4.4	2280	206.3	20.7
300 (B)	5090	17.0	4.8	2399	176.3	35.3
Difference (A minus B)	4455	−1.1†	−0.4	−119†	30.0**	−14.6**
Difference Necessary for Significance. Odds 19:1		−1.60†			7.80	−5.22

*Thirty-six square feet of bedding space.
**Differences are considered significant.
†Differences are considered insignificant.

unit area of bedding space and significantly increased the amount of electricity necessary to maintain the proper temperature. However, the number of plants produced per unit area of bedding space is far greater than the increase in electrical consumption. This greater plant production combined with the slight, though significant, increase in electrical consumption, markedly decreased the amount of electricity required to produce unit number of plants. Since a low electrical consumption combined with a high plant production is highly desirable, the data show that "crowded" bedding will markedly decrease the cost of producing plants in electrically heated hotbeds.

The data also show that "crowded" bedding slightly and insignificantly reduced the production of plants per root and had no effect on the mean weight of the individual plants. The marked similarity of the individual plants between the two treatments was a striking feature of the experiment. It was expected that "crowded" bedding would produce many plants with long, drawn-out spindling stems. However, no marked difference in this respect was evident.

The data, presented in Table II, show the effect of "crowded" bedding on the condition of the bedded roots at the end of the plant production period. Three classes of roots were made: (a) wholly rotted,

TABLE II—CONDITION OF ROOTS AT END OF PLANT PRODUCTION PERIOD (1939, 1940, 1941, AND 1942)

Number of Roots Per Unit Area*	Soundness of Bedded Stock		
	Wholly Rotted (Per Cent)	Partially Rotted (Per Cent)	Sound (Per Cent)
600 (A)	6.93	5.43	87.65
300 (B)	3.23	3.67	92.83
Difference (A minus B)	3.70**	1.76**	−5.18†
Differences Necessary for Significance. Odds 19:1	2.34	1.04	6.54

*Thirty-six square feet of bedding space.
**Differences are considered significant.
†Differences are considered insignificant.

(b) partially rotted and (c) sound. Roots showing rots on 90 per cent or more of their surfaces were considered as wholly rotted; those showing the absence of rots on 90 per cent or more of their surfaces were classed as sound; and those which were intermediate between these two classes were considered as partially rotted. The data show that most of the roots remained in the sound condition during the plant production period. Although "crowded" bedding significantly increased the per cent of wholly rotted and partially rotted roots, the differences are rather narrow and are considered of no great practical importance. In other words "crowded" bedding failed to materially increase the rotting of the bedded roots. Thus, it seems feasible that "crowded" bedding can be recommended to the grower who uses sound seedstock and practices sanitation in all phases of plant production.

CONCLUSIONS AND SUMMARY

"Crowded" bedding, consisting of placing approximately twice as many roots per unit area of bedding space as is ordinarily practiced, markedly increased plant production per unit area of bedding space and had little effect on the characteristics of the individual plant. Furthermore, "crowded" bedding did not materially increase rotting of the bedded roots.

Why are Single Plant Yields of Sweetpotato Highly Variable Within Plots?[1]

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IT HAS long been observed that single hills (single plants) of the sweetpotato differ enormously in yield even within a few feet of row in high-yielding and apparently excellent plantings. Although the tops of the plants early in the season may appear quite uniform and suggest equal productivity, harvesting the roots usually shows yield variations ranging from nothing to 2, 3, 4, or more pounds per plant.

It seemed probable that these wide variations among apparently strong, healthy, and productive plants might be due to inadvertent inequalities at transplanting, in character of sprouts, amount of roots on sprouts, or even to mutant differences in mother roots from which sprouts or cuttings were derived. A cooperative study was designed to determine whether mother roots, mode of propagation, or any other recognizable condition could be associated with the productivity of individual hills.

MATERIALS AND METHODS

The Porto Rico variety was used. A number of mother roots was chosen at random and a supply of vine cuttings developed from each, the cuttings from a single root being kept separate from all others. Cuttings and sprouts were also produced from a random lot of roots. Sprouts and cuttings of differing size, with and without roots, were obtained from these. At the time of transplanting detailed data were recorded for each sprout or cutting planted in the field, including source or kind of propagating piece, length, weight, amount of roots, and number and size of leaves.

Sixteen different sources of material, or "treatments", were observed for two years at Beltsville, Maryland, and Meridian, Mississippi, and for one year at Clemson, South Carolina. Each test in the field consisted of four randomized blocks, each block containing 16 rows of 25 plants 18 inches apart. Rows were 4 feet apart. The transplanting was done by skilled workers who took special care to handle the material uniformly. Each block was set entirely by a single worker.

Beginning the day after transplanting, a detailed history of the performance of each plant was maintained, including response to transplanting, time of resumption of growth, leaf number, and length of new stem growth at various time intervals, and finally on the number, size, and total weight of sweetpotatoes produced.

Several plant responses, conditions, and characters of the propagating piece were analyzed together with ultimate yield, by the covariance method, in efforts to discover some critical condition or stage of growth that might bear a causal relationship to the final yield.

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[1] The authors acknowledge the assistance of Victor R. Boswell in the planning of these studies and in the preparation of this report.

The 16 "treatments" are listed here, together with the identifying symbols that appear in the tables:

1. Non-rooted cuttings from root No. 1 (NC–1)
2. Non-rooted cuttings from root No. 2 (NC–2)
3. Non-rooted cuttings from root No. 3 (NC–3)
4. Non-rooted cuttings from root No. 4 (NC–4)
5. Non-rooted cuttings from root No. 5 (NC–5)
6. Non-rooted cuttings from root No. 6 (NC–6)
7. Non-rooted cuttings from root No. 7 (NC–7)
8. Non-rooted cuttings from root No. 8 (NC–8)
9. Rooted cuttings from root No. 1 (RC–1)
10. Rooted cuttings from root No. 2 (RC–2)
11. Non-rooted cuttings from stem end sprouts of random lot of 50 roots (NCS)
12. Non-rooted cuttings from distal end sprouts of random lot of 50 roots (NCD)
13. Rooted cuttings from stem end sprouts of random lot of 50 roots (RCS)
14. Rooted cuttings from distal end sprouts of random lot of 50 roots (RCD)
15. Draws or sprouts from stem ends of random lot of 50 roots (DS)
16. Draws or sprouts from distal ends of random lot of 50 roots (DD)

RESULTS

Some incidental observations earlier, in other work, had suggested that the mode of propagation and condition of the propagating piece might be responsible for great differences in yield of sweetpotatoes. When only the mean yield per plant, for each treatment as a single value at each place for each year is considered, the variations in response to treatment in the five tests render differences between treatments non-significant (Table I). Likewise, when rooted versus non-rooted cuttings or plants from distal versus those from stem ends are similarly compared, no significant differences are found. Differences among cuttings from the eight roots, all treated alike, were as great as among differently handled propagating pieces. Still, field observations and the detailed data suggested that certain differences associated with treatments were rather large and might have statistical significance if compared on the basis of the detailed data.

TABLE I—SUMMARY OF TOTAL YIELDS OF SWEETPOTATOES IN THE FIVE TESTS (VARIANCE BETWEEN AND WITHIN BLOCKS NOT DETERMINED)

Treatment	Yield Per Plant* (Grams)	Treatment	Yield Per Plant* (Grams)
Non-rooted cuttings from root 1	317	Rooted cuttings from root 1	340
Non-rooted cuttings from root 2	320	Rooted cuttings from root 2	303
Non-rooted cuttings from root 3	369	Non-rooting cuttings from stem end	295
Non-rooted cuttings from root 4	282	Non-rooting cuttings from distal end	307
Non-rooted cuttings from root 5	269	Rooted cuttings from stem end	319
Non-rooted cuttings from root 6	379	Rooted cuttings from distal end	356
Non-rooted cuttings from root 7	273	Draws from stem end	368
Non-rooted cuttings from root 8	328	Draws from distal end	325

*Differences not significant when referred to the interaction treatments x tests.

Tables II, III, and IV show that when each test is analyzed in detail, using the "within *plot*" variance as the measure of error, highly significant differences occurred among the several treatments — differences in character of material transplanted, in rate of leaf development and relative vigor; and in yield of roots per plant. The question arises as to the importance and meaning of such striking differences among treatments, within each of the five tests, when there was non-significance among them upon combining the treatment data for the tests. It can only be concluded that the apparent effects of treatments, although large enough in single tests, were so lacking in consistency as to be of no practical value as an aid to improving yields. It would

TABLE II—RELATION OF METHOD OF PROPAGATION TO DEVELOPMENT OF SWEETPOTATO, BELTSVILLE, MARYLAND (ERROR BASED ON PLANT VARIANCE WITHIN PLOTS)

Treatment	Size of "Set" (Grams)	Number of Leaves At			Yield Per Plant (Grams)	Leaf Area At		Days to First Growth	Plant Vigor 32 Days (Index)
		8 to 11 Days	19 to 22 Days	32 Days		8 to 9 Days (Index)	18 to 19 Days (Index)		
					1937				
1 (NC1)	7.6	1.9	4.5	19	450	0.6	1.2	6.5	2.7
2 (NC2)	7.0	1.9	4.1	18	379	0.5	1.1	6.7	2.5
3 (NC3)	5.9	1.9	5.0	23	461	0.5	1.2	6.5	2.7
4 (NC4)	7.7	2.2	5.2	22	329	0.6	1.3	5.7	2.8
5 (NC5)	6.7	1.9	4.7	22	370	0.6	1.2	5.5	2.8
6 (NC6)	6.9	2.0	4.7	23	533	0.6	1.2	5.3	2.8
7 (NC7)	6.5	1.7	4.6	20	352	0.4	1.1	7.3	2.7
8 (NC8)	6.1	1.7	4.5	21	446	0.3	1.1	6.9	2.7
9 (RC1)	7.4	2.5	6.8	29	385	0.8	1.8	3.5	3.4
10 (RC2)	10.0	2.9	6.7	31	461	1.0	1.8	3.0	3.2
11 (NCS)	5.8	1.7	4.0	17	398	0.4	1.1	7.8	2.3
12 (NCD)	3.6	1.0	3.4	16	389	0.2	1.0	8.7	2.2
13 (RCS)	7.1	2.7	6.2	32	375	0.9	1.6	3.6	3.3
14 (RCD)	6.0	2.3	5.7	30	422	0.9	1.5	3.7	3.1
15 (DS)	9.0	5.7	17.0	55	539	1.7	—	2.1	3.8
16 (DD)	6.4	6.3	13.0	41	422	1.5	—	2.6	3.1
Difference required for significance at 1 per cent point	0.70	0.34	0.72	1.40	60	0.14	0.12	0.82	0.21
					1938				
1 (NC1)	5.6	1.3	5.9	20	403	1.0	1.6	5.2	2.8
2 (NC2)	5.2	1.5	6.0	19	355	1.0	1.5	5.3	2.7
3 (NC3)	5.6	1.5	5.9	18	392	1.0	1.5	5.0	2.7
4 (NC4)	5.4	1.1	5.0	15	242	1.0	1.2	5.9	2.4
5 (NC5)	5.0	1.3	4.4	13	218	1.0	1.1	5.4	2.3
6 (NC6)	5.0	1.3	5.2	14	439	1.0	1.3	5.5	2.3
7 (NC7)	5.3	1.3	5.4	15	202	1.0	1.3	5.4	2.4
8 (NC8)	4.3	1.4	5.5	16	375	1.0	1.3	5.3	2.4
9 (RC1)	10.7	1.3	10.5	35	459	1.1	2.7	5.4	3.7
10 (RC2)	9.1	1.2	10.5	32	366	1.1	2.5	5.3	3.1
11 (NCS)	4.1	1.3	4.9	17	299	1.0	1.4	5.1	2.5
12 (NCD)	4.9	1.1	4.4	14	289	0.9	1.2	5.4	2.4
13 (RCS)	8.7	1.1	10.5	31	356	1.1	2.2	5.5	3.3
14 (RCD)	11.1	1.1	10.7	33	385	1.1	2.5	5.3	3.2
15 (DS)	7.8	1.4	16.3	44	386	1.2	2.6	5.4	3.3
16 (DD)	6.5	1.2	13.0	36	362	1.1	2.1	5.8	3.2
Difference required for significance at 1 per cent point	0.41	0.08	0.5	1.4	104	0.04	0.14	0.25	0.24

TABLE III—RELATION OF METHOD OF PROPAGATION TO DEVELOPMENT OF SWEETPOTATO, FLORENCE, SOUTH CAROLINA, 1938 (ERROR BASED ON PLANT VARIANCE WITHIN BLOCKS)

Treatment and Symbol	Size of "Set" (Grams)	Number of Leaves At			Yield Per Plant (Grams)	Leaf Area At 9 Days (Index)	Branch Length At		Plant Vigor at 36 Days (Index)
		9 Days	21 Days	36 Days			21 Days (Cms)	36 Days (Cms)	
1 (NC1)	7.1	1.6	3.7	12.8	423	2.0	2.4	9.2	3.3
2 (NC2)	6.3	1.6	3.4	10.1	417	1.8	1.5	5.7	2.7
3 (NC3)	6.1	1.5	3.9	13.8	513	2.0	2.0	8.7	3.4
4 (NC4)	7.0	1.6	3.9	12.2	421	1.8	1.8	7.1	3.2
5 (NC5)	5.5	1.4	3.1	8.9	287	1.6	1.6	7.2	2.7
6 (NC6)	5.5	1.3	3.2	9.2	407	1.5	1.3	8.7	2.4
7 (NC7)	6.5	1.4	3.6	12.7	374	1.8	2.0	7.0	3.3
8 (NC8)	6.8	1.5	3.4	12.8	462	1.8	1.9	9.1	3.0
9 (RC1)	5.8	2.1	4.0	14.0	484	2.2	2.3	10.5	3.0
10 (RC2)	4.8	1.2	2.8	6.4	353	1.3	0.9	4.3	2.1
11 (NCS)	5.8	1.6	3.6	11.4	449	1.9	1.6	8.3	3.1
12 (NCD)	6.4	1.9	3.4	12.8	518	2.0	2.0	8.9	2.9
13 (RCS)	6.1	1.8	3.3	13.7	508	1.9	1.7	8.6	3.0
14 (RCD)	5.8	1.9	3.0	11.9	525	1.9	1.5	8.4	2.8
15 (DS)	5.7	3.4	3.0	22.6	607	1.5	3.3	13.7	3.4
16 (DD)	5.2	3.7	4.4	26.1	531	1.4	5.6	16.4	3.7
Difference required for significance at 1 per cent point	0.70	0.48	1.86	7.0	270	0.84	0.94	5.4	0.98

seem that unidentified factors beyond control of the operators were, despite all precautions, responsible for apparent treatment differences.

It seemed possible that the apparent treatment differences may have been associated with uncontrolled differences in character or early development of the transplants. Therefore covariance calculations were made on the individual plant readings from each test, as shown in Table V. The most striking point about the results in the table is the lack of consistency of the figures for the early life of the transplants among the five tests. After about a month, however, the pattern of the individual plants seemed to have been determined so that the yielding power might be evaluated with a fair to low degree of dependability. The differences among coefficients of correlation for treatment totals were generally non-significant; however, within the 25-plant plots correlations between yield and the several other observations or measurements were generally significant statistically and nearly always of relatively low magnitude. For Meridian in 1938 nearly all criteria of early plant development were significantly correlated with ultimate yield, both among treatments and within plots, but this was exceptional.

There was a tendency for delayed recovery of transplants to reduce the ultimate yield, but the differences in time of appearance of new growth were small, and the correlations with yield were generally non-significant. In three of the five tests there were small but significant effects of size of draw or cutting within plots upon yield, but no significant effect among treatments. Within plots, the magnitude and significance of correlations between leaf number and yield and estimated leaf area and yield tended to increase at successively later observations made approximately 1 week, 3 weeks, or 5 weeks after transplanting. Here again, however, inconsistencies and unexplained discrepancies, as well as relatively low r values permit no very definite assignment

TABLE IV—RELATION OF METHOD OF PROPAGATION TO DEVELOPMENT OF SWEETPOTATO, MERIDIAN, MISSISSIPPI (ERROR BASED ON PLANT VARIANCE WITHIN BLOCKS)

Treatment	Size of "Set" (Grams)	Number of Leaves At			Yield Per Plant (Grams)	Leaf Area At		Plant Vigor At 31 to 34 Days (Index)
		6 to 8 Days	23 to 25 Days	31 to 34 Days		6 to 8 Days (Index)	16 to 17 Days (Index)	
			1937					
1 (NC1)	11.1	2.2	8.7	29	69	4.4	19	3.0
2 (NC2)	11.3	2.4	8.8	29	103	5.2	17	3.0
3 (NC3)	11.0	2.4	8.9	27	102	5.0	20	3.2
4 (NC4)	8.6	2.3	8.8	31	100	4.6	19	3.1
5 (NC5)	10.2	2.6	8.8	26	131	5.8	18	3.0
6 (NC6)	8.1	2.2	12.9	39	114	6.2	33	3.3
7 (NC7)	8.8	2.1	9.4	28	77	5.5	24	3.1
8 (NC8)	9.4	1.9	7.8	27	76	4.1	15	2.8
9 (RC1)	16.1	3.2	13.1	31	71	6.4	20	3.0
10 (RC2)	18.0	3.1	11.8	31	90	6.3	20	2.9
11 (NCS)	11.0	2.4	10.7	33	88	4.4	20	3.2
12 (NCD)	11.3	2.6	10.7	36	90	5.0	19	3.2
13 (RCS)	18.2	4.7	12.9	36	94	7.0	21	3.1
14 (RCD)	18.0	4.8	21.6	55	78	12.9	15	3.4
15 (DS)	6.9	3.8	25.8	55	107	16.4	44	3.5
16 (DD)	6.7	3.6	19.6	51	107	13.5	36	3.3
Difference required for significance at 1 per cent point	1.6	0.4	1.4	4.4	24	1.4	4	0.2
			1938					
1 (NC1)	17.5	3.3	30	53	242	21	74	3.4
2 (NC2)	15.7	3.4	35	59	345	20	70	3.4
3 (NC3)	16.0	3.8	38	61	379	27	105	3.7
4 (NC4)	14.0	3.5	40	70	319	21	70	3.6
5 (NC5)	15.0	3.6	36	62	337	20	69	3.4
6 (NC6)	15.0	3.4	38	67	403	21	67	3.7
7 (NC7)	14.6	3.8	41	65	358	22	70	3.7
8 (NC8)	15.0	3.8	40	64	281	22	74	3.5
9 (RC1)	11.2	3.9	30	52	303	24	62	3.6
10 (RC2)	6.3	3.4	26	43	246	13	43	3.2
11 (NCS)	13.9	3.2	31	53	239	17	55	3.4
12 (NCD)	14.3	2.8	29	55	248	15	49	3.3
13 (RCS)	7.4	4.7	33	58	262	17	51	3.6
14 (RCD)	7.0	4.8	34	57	369	17	60	3.5
15 (DS)	8.6	3.8	32	49	203	11	40	3.3
16 (DD)	8.7	3.8	30	43	204	11	38	3.2
Difference required for significance at 1 per cent point	0.6	0.4	3.2	5.2	146	2.6	8	0.2

of reasons for the good or poor performance of most individual plants. Ratings of plant vigor at about 5 weeks gave results roughly similar to those of leaf number.

One important observation was recorded that is not revealed by the figures presented. With the planting distance used in these studies, competitive effects tended to exaggerate or accentuate the poor performance of weak-growing or late-starting individuals. This, of course, does not explain why some plants start off late or with weak growth, but does help explain why they may never equal their vigorous neighbors. Interesting evidence could be obtained on the element of competition by repeating these studies at two widely different planting distances, for example, 1½ by 4 feet and 4 by 4 feet. Even if late-

TABLE V—CORRELATIONS BETWEEN TREATMENTS AND WITHIN PLOTS†

Factors Correlated and Material Involved	Location and Year of Test				
	Beltsville 1937	Beltsville 1938	Florence 1938	Meridian 1937	Meridian 1938
Original sprout or cuttings size and yield	(r)	(r)	(r)	(r)	(r)
Between treatments	0.310	0.456	-0.183	-0.393	0.361
Within plots	0.187*	0.188*	-0.040	0.001	0.176*
Days to first growth and yield					
Between treatments	-0.355	-0.251	—	—	—
Within plots	-0.098	-0.221*	—	—	—
Leaf area rating, 6 to 9 days, and yield					
Between treatments	0.038	0.424	0.062	0.195	0.711*
Within plots	0.189*	0.202*	0.135*	0.233*	0.334*
Leaf area rating, 16 to 19 days, and yield					
Between treatments	0.043	0.562*	—	0.233	0.698*
Within plots	0.038	0.504*	—	0.419*	0.420*
Leaf number 6 to 9 days and yield					
Between treatments	0.490*	0.142	0.504*	0.142	0.021
Within plots	0.191*	0.230*	0.079*	0.230*	0.146*
Leaf number, 19 to 25 days and yield					
Between treatments	0.480	0.442	0.101	0.109	0.665*
Within plots	0.263*	0.296*	0.247*	0.295*	0.501*
Leaf number, 31 to 36 days, and yield					
Between treatments	0.506*	0.508*	0.532*	0.110	0.724*
Within plots	0.770*	0.368*	0.346*	0.309*	0.470*
Plant vigor, 31 to 36 days, and yield					
Between treatments	0.390	0.603*	0.314	0.410	0.742*
Within plots	0.051	0.495*	0.328*	0.326*	0.397*

†Values marked * are statistically significant.

starting or weak-growing plants were to suffer less suppression from vigorous neighbors at wide spacings, such a design probably would still fail to reveal why some apparently normal plants produce very low yields.

SUMMARY

1. Details of growth and ultimate yields of individual sweetpotato plants were recorded in replicate plots set the same day with rooted and non-rooted cuttings from selected and from random lots of roots, and set with draws or sprouts from random lots of roots.
2. Five tests in three locations during two years embraced a total of 8000 individual plant records.
3. Yields per plant were not consistently correlated with kind of propagating piece or portion of the mother root from which cuttings or sprouts were derived.
4. Little to practically none of the variation in yield per plant could be associated consistently with any evident feature of the individual propagating piece or the newly established normal plant in the field.
5. The cause of great differences in yield of normal plants within a plot is still unknown.

Factors Influencing the Relative Humidity of the Air Immediately Surrounding Sweet Potatoes During Curing

By J. M. Lutz, *U. S. Department of Agriculture, Meridian, Miss.*

IT has been well established that the rate and degree of curing of sweetpotatoes are influenced by the temperature and humidity surrounding the roots during the curing period. Both in commercial practice and experimentally, the relative humidity determined is that of the air in the room in which the sweetpotatoes are cured rather than that of the air immediately surrounding the roots. It was, therefore, thought desirable to determine the relationship of the relative humidity of the air in the room to that surrounding the sweetpotatoes during curing, and the influence of temperature, humidity, and air circulation on this relationship, in order to establish a basis for maintaining conditions in a curing room to obtain the desired humidity immediately surrounding the sweetpotatoes.

Weimer and Harter (4) found that periderm formation in the sweetpotato takes place very rapidly under high humidity conditions (96 per cent) at 33 degrees C (91.4 degrees F). They also found that the healed surface of a wounded sweetpotato forms an effective barrier against infection by microorganisms.

Lauritzen and Harter (2) reported that resistance to infection by Rhizopus was developed in halved roots of sweetpotatoes that had been held at relative humidities of 89 to 97 per cent. They suggested that this resistance has a possible relation to cork formation.

Artschwager and Starrett (1) found that at temperatures of around 84 degrees F wound periderm formation was most rapid at a relative humidity of 90 to 95 per cent and the rate decreased with decreasing humidity. The most rapid wound periderm formation occurred at 31.7 degrees C (89.1 degrees F). The rate of suberization and wound periderm formation decreased with decreasing temperatures. The lowest temperature at which they observed wound periderm formation was 12.5 degrees C (54.5 degrees F), but the process was very slow at this temperature.

MATERIALS AND METHODS

These investigations were conducted with Porto Rico sweetpotatoes at the United States Horticultural Field Station, Meridian, Mississippi, using roots which had been grown on the Station farm. The roots were harvested in the regular manner and placed in standard bushel crates. These in turn were then placed under curing conditions immediately after harvesting. A continuous record of the temperature and humidity of the air in the curing rooms was obtained with hygrothermographs checked at frequent intervals with a sling psychrometer. The temperature in the unheated room ranged from 56 to 77 degrees F and averaged 68 degrees F. The relative humidity in that room also varied, ranging from 52 to 79 per cent and averaged 65 per cent. In the other three curing rooms the temperature was maintanied at

TABLE I—COMPARISON BETWEEN RELATIVE HUMIDITY IN CENTER OF SWEETPOTATO CRATES AND IN THE CURING ROOM DURING A PERIOD OF TEN DAYS

Method of Curing	Location	Relative Humidity After Curing Period Indicated (Per Cent)			
		1 Day	3 Days	6 Days	10 Days
A High humidity; no air circulation	Crate	99	97	93	87
	Room	67	68	70	76
	Difference	32	29	23	11
B High humidity; air circulation	Crate	99	95	87	80
	Room	80	75	75	76
	Difference	19	20	12	4
C Low humidity; no air circulation	Crate	92	69	45	44
	Room	47	49	43	44
	Difference	45	20	2	0
D Not cured—held in unheated room	Crate	94	93	92	99
	Room	73	58	70	76
	Difference	21	35	22	23

85 degrees F by thermostatic control, and the humidity was fairly constant as is shown in Table I.

The humidity immediately surrounding the roots was obtained by a method suggested by Smith (3). The moisture content was determined for approximately 3 grams of viscose filaments which were placed in copper netting envelopes in the center of the crate of sweetpotatoes. When it was desired to determine the humidity, the viscose was rapidly transferred with a pair of tweezers to a tightly stoppered weighing bottle. After weighing, the viscose was dried in vacuum at 40 degrees C for 48 hours and the moisture content was calculated from the weight loss in drying. From this the relative humidity was determined by referring to a chart made from data previously obtained on the moisture content of viscose at various relative humidities at the temperature used in the experiment. Three samples of viscose were taken from the center of each of the crates as well as from each of the curing room conditions at each time of sampling. The data were analyzed by the method of analysis of variance and it was found that a difference between treatments of 3 per cent was necessary for significance (odds 19: 1) and of 4 per cent for high significance (odds 99: 1).

RESULTS

Although these experiments were conducted in both 1941 and 1942, only those of the latter year are included as the results of the two years are practically identical.

It can be noted in Table I that except at the end of the 10-day period at low humidity, the humidity was higher in the center of the crates than in the surrounding air as a result of the moisture transpired from the sweetpotatoes. In all cases except for the 6-day period at low humidity, these differences between the humidity within the crate and the room were highly significant. Air circulation in the curing room, as would be expected, resulted in less difference between the relative humidity inside the crate and in the room. Although the room humidity with air circulation (method B) was higher than in method A, which had no air circulation, the humidity in the crate was higher in the latter case, except at the 1-day period when there was no difference. The relative humidity in the centers of the crates of sweetpotatoes decreased during curing at both high-humidity conditions. This is doubtless due to suberization and wound periderm formation early in the curing period which retarded later moisture loss from the roots. With the sweetpotatoes that were not cured but held in an unheated room, the humidity of the air around the roots remained considerably higher throughout the period than that of the air in the room. This is apparently due to the fact that little suberization or wound periderm formation took place because the temperature was too low; thus the rate of moisture loss continued high.

At the beginning of the period the humidity immediately surrounding sweetpotatoes held under low humidity was much higher than that of the surrounding air. At the end of the period there was no difference. It is possible that under low humidity conditions surface drying results in the formation of a surface layer that retards moisture loss, or else rapid and extensive water loss from the sweetpotato results in the reaching of an equilibrium between the surface of the roots and the surrounding air. Weimer and Harter (4) suggest that the drying out of injured cells may exert some retarding or inhibiting action against decay-producing organisms. Curing under low humidity conditions is, however, much less effective in controlling decay in storage than is curing under high humidity conditions because wound periderm formation is so much delayed.

Although it has been shown (1, 4) that suberization and wound periderm formation occur most readily at very high relative humidities — 90 per cent or above — in commercial practice the humidity is generally lower than this. The problem frequently is to maintain a high enough humidity during curing. Records obtained in several sweetpotato houses in the vicinity of Meridian, Mississippi, showed that the highest average relative humidity during curing was 80 per cent and the lowest 60 per cent. On the basis of the results in Table I, it appears that in commercial curing practice, transpiration effects would cause the relative humidity of the air immediately surrounding all but the outer layers of sweetpotatoes to approach the optimum for suberization and wound periderm formation, even though the humidity of the air in the room might be somewhat below the optimum. It would seem however that the roots at the tops, bottoms and sides of crates or bins would be exposed to air of about the same humidity as that prevailing in the curing room. If this was relatively dry, wound periderm formation would be delayed. Thus, although most of the roots are doubtless surrounded by air of high humidity, some of them will not cure properly unless the humidity of the air throughout the room is maintained near the recommended level. Important losses may readily occur in roots that are not cured promptly and thoroughly. Furthermore, under conditions of very low humidity in the room it is not likely that the humidity even in the center of the crates of sweetpotatoes would be maintained high enough throughout the curing period.

SUMMARY

A method is described for determining humidity of the air immediately surrounding sweetpotatoes during curing, by means of determining the moisture content of viscose filaments.

The humidity of the air immediately around the sweetpotatoes well within the package was higher than that of the air of the room (outside the package) in which they were cured. This difference becomes less as the roots become cured. Air circulation resulted in less difference between the humidity of the air in the crate of sweetpotatoes and that prevailing in the curing room, than was the case where there was no circulation.

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The Effect of Exposure to Low Temperatures on Plant Production of the Porto Rico Sweetpotato

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IN the coastal plain area of South Carolina, winter temperatures are generally mild. Thus, the use of artificial heat in sweetpotato houses is considered unnecessary to maintain temperatures within the optimum range for storage. However, cold spells with minimum temperatures from 15 to 20 degrees F, and varying from 1 or 2 days to 1 or 2 weeks, sometimes occur. During these cold periods the heat of respiration is frequently insufficient to maintain the storage rooms at the proper temperature. As a result, the temperature within the storage house gradually declines and, undoubtedly, remains below the optimum range for storage until the weather moderates. Although previous investigations (1, 2, 3) have shown that exposure to cold for relatively long periods makes the roots susceptible to storage rots and induces internal breakdown of the flesh, no experimental information is available on the effect of this factor on plant production of the bedded roots. To show the effect of exposure to low temperatures on plant production, experiments were conducted at Clemson College from 1939 to 1943 inclusive. The most pertinent results are presented herein.

MATERIALS AND METHODS

In these tests roots of the Unit 1 strain of the Porto Rico were used. Each year at the end of the storage period six comparable lots each consisting of 50 roots of U. S. No. 1 and U. S. No. 2 grade were prepared. Lots 1, 3 and 5 were placed in a room maintained from 38 to 42 degrees F, and lots 2, 4 and 6 were placed in a room maintained from 50 to 55 degrees F. Lots 1 and 2 remained in their respective rooms for 4 days; lots 3 and 4 for 7 days; and lots 5 and 6 for 14 days. Each comparable pair was bedded at the same time side by side in a greenhouse bench and subjected to the same conditions of temperature, moisture and light throughout the period of the experiment. The bedding soil consisted of a mixture of equal parts of river bed sand and clay loam. The first plants were pulled from 3 to 4 weeks after the roots were bedded, and pulling was continued at intervals of 1 week until five pullings were made.

DISCUSSION OF RESULTS

The data, presented in Table I, show the effect of the exposures to 40 degrees F on plant production. The figures show that only the 7-day and 14-day exposures lowered plant production of the roots. The difference in mean number of plants per root is barely significant for the 7-day exposure and is highly significant for the 14-day exposure. The results on grams of roots required to produce 1 gram of plant are similar. Here again, the difference is insignificant for the 4-day exposure; barely significant for the 7-day exposure; and highly significant for the 14-day exposure. Thus, the data indicate that while relatively

TABLE I—INFLUENCE OF SHORT EXPOSURES TO LOW TEMPERATURE ON THE PLANT PRODUCTION OF THE PORTO RICO SWEETPOTATO (1939–43)

Temperature Treatment	Mean Weight Roots (Grams)	Mean Number Plants Per Root	Mean Weight Plant (Grams)	Grams Root Per Gram Plant	Plants per 50 Pound Bushel
40 degrees F. for 4 days	179.6	13.4	4.1	3.26	1692
55 degrees F. for 4 days (check)	177.9	13.7	4.1	3.21	1747
40 degrees F. for 7 days	179.0	13.1	3.9	3.49	1660
55 degrees F. for 7 days (check)	178.3	15.4	3.9	2.93	1959
40 degrees F. for 14 days	175.5	10.5	4.0	4.22	1357
55 degrees F. for 14 days (check)	176.9	15.1	3.7	3.20	1936
Differences Necessary for Significance; Odds 19:1		2.38		0.578	

short exposures to low temperature have no effect on plant production, extended periods of exposure have marked effects. In general, the longer the exposure, within limits, the lesser will be the plant production.

In 1939 and 1940 observations were made on the soundness of the bedded roots immediately after the plant production period. Three classes were evident: (a) completely rotted, (b) partially rotted, and (c) sound. Roots showing rots on 90 per cent or more of their surfaces were classified as completely rotted; those showing the absence of rots on 90 per cent or more of their surfaces were classified as sound; and those intermediate between these two classes were classified as partially rotted. The data are presented in Table II. They show that although the 4-day exposure had no effect on rotting, the 7- and 14-day exposures produced considerable rotting. Thus, the direct association of the degree of rotting and plant production of the roots may explain, partially at least, the lower plant production with the relatively long exposures to cold.

TABLE II—CONDITION OF ROOTS AT END OF PLANT PRODUCTION PERIOD 1939 AND 1940

Temperature Treatment	Soundness of Bedded Roots		
	Wholly Rotted (Per Cent)	Partially Rotted (Per Cent)	Whole (Per Cent)
40 degrees F for 4 Days	6.0	4.0	90.0
55 Degrees F for 4 days (check)	6.0	7.0	87.0
40 degrees F for 7 days	13.0	15.0	72.0
55 degrees F for 7 days (check)	1.0	5.0	94.0
40 degrees F for 14 days	37.0	8.5	54.5
55 degrees F for 14 days (check)	12.0	6.0	82.0

In general, these results have an important connection with those of Kimbrough and Bell (2). These investigators showed that exposure to 40 degrees F for 1 week or longer markedly lowers the keeping quality of the roots. These results show that exposure to 40 degrees F, for similar periods lower plant production also.

CONCLUSIONS AND SUMMARY

At the end of the regular storage period, roots of the Unit 1 strain of the Porto Rico sweetpotato were exposed to temperatures of 40 degrees F for periods of 4 days, 7 days and 14 days. The 7- and 14-day exposures decreased the number of plants per root and per bushel, increased the grams of root required to produce unit weight of plant and induced marked rotting of the bedded roots. Thus, exposure to temperatures below the optimum range in storage for relatively long periods is likely to lower the plant producing capacity of the roots.

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Prevention of Potato Seed Piece Decay in Southern Idaho[1]

By JAMES E. KRAUS and GEORGE W. WOODBURY, *University of Idaho, Moscow, Idaho*

IN the irrigated potato areas of southern Idaho, the land is usually irrigated before planting if there has not been sufficient rainfall to insure a good stand of plants. Potatoes are rarely irrigated before emergence and usually the first irrigation is not applied until 3 to 5 weeks after planting. Such conditions of comparatively high soil moisture are ideal for suberization of fresh cut potato sets after planting. Consequently, it is usually unnecessary for sets to be cured or corked over before planting. Because of these planting conditions the usual and recommended practice is to cut the sets and plant them immediately. This practice has proven very satisfactory where soil moisture is optimum for germination.

For several years some growers have reported poor stands of potatoes when following the practice indicated above. In the majority of reported instances and where such fields were examined, the cut seed pieces were found to be completely decayed 5 to 10 days after planting. In most of these fields soil moisture was adequate for germination. Examination of partially decayed sets indicated that they might have been injured previous to planting. It was also ascertained in talking with some growers that the seed had been cut out in the open rather than in the storage cellar. Indications were that the cut sets had been exposed for several hours to high temperature, wind, or other rapidly drying conditions.

METHODS AND MATERIALS

In 1940 the junior author started field experimental work to determine the factors causing seed piece decay and the most suitable methods of handling cut potato sets under southern Idaho conditions. The experimental work was continued in the greenhouse and in the field by the senior author in 1941 and 1942. Russet Burbank (Netted Gem) potatoes were used in all experiments. The treatments and methods varied from year to year but they were similar enough so that they were for the most part comparable.

The principal types of seed handling for the field experiments were as follows:

1. Exposure of cut sets for 24 to 240 hours in the storage cellar at temperatures of 50 to 55 degrees F, and relative humidities of 70 to 80 per cent.
2. Exposure of cut sets for 6 to 240 hours in the shade in an open machine shed. The temperature varied from 40 degrees at night to 80 degrees F in the day time and the corresponding relative humidities varied from 85 to 30 per cent.

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3. Exposure of cut sets for 6 to 240 hours in a warm room at temperatures of 75 to 90 degrees F and relative humidities of 30 to 50 per cent.
4. Exposure of uncut tubers for several days in the greenhouse at temperatures of 70 to 80 degrees F and relative humidities of 30 to 50 per cent. These were then cut and the sets exposed 24 hours in the warm room.
5. Treatment of cut sets with various dusts and solutions to determine subsequent effect on drying.

In two years seed pieces of the various treatments were planted at three different dates. Other experiments were conducted in the greenhouse to determine the inter-relationship of temperature and humidity on drying and subsequent decay of sets.

Data were taken on stand of plants, yield, and grade.

RESULTS

Although there was some variation in the data for the different years, the general results from comparable treatments are in good agreement. Therefore, the results of all years will be discussed together. It was of course expected that certain treatments might vary from year to year because of differences in temperatures at the time of exposure of sets.

Sets cut and left in the storage cellar gave almost perfect stands and were as good as sets cut and planted immediately (check) regardless of length of time of exposure. These results were to be expected because the temperature and humidity in most southern Idaho cellars are ideal for the formation of wound periderm. Consequently, there was no excessive drying of the cut surface.

As indicated previously, the effect of exposure of cut sets in the open varied in different years and on different planting dates, depending on the length of exposure and on the prevailing temperature and humidity during exposure. If during the period of exposure, the temperature was 50 to 60 degrees F or below and the humidity was relatively high (above 60 per cent) there was very little drying of the cut surface and no significant reduction in stand. In most instances there was less effect on decay and stand with early plantings than with later ones, and this was directly associated with lower temperatures and higher humidities during the cutting period.

Cut sets exposed to relatively high temperatures in a warm room always decayed more, resulting in poorer stands and lower yields. In many instances exposure of cut sets to temperatures above 70 degrees F for as little as 3 hours resulted in extensive seed piece decay. Under these conditions as the length of time of exposure increased the amount of decay increased.

Treatment of cut sets with various dusts including lime, sulfur, and a mixture of the two tended to increase decay, possibly because of quicker drying of the cut surface. Sets treated with solutions of Semesan Bel, sodium thiosulfite, and other solutions decayed as badly or worse than those untreated.

There was some indication that exposure of tubers to high temperatures (above 70 degrees F) previous to cutting had a tendency to increase decay of the sets if the sets from such tubers were subsequently exposed to drying conditions before planting.

Tests in the greenhouse indicated that high temperatures were not detrimental and did not necessarily increase decay if the relative humidity could be maintained between 90 and 100 per cent. In one case sets did not decay after exposure to a temperature of 90 to 110 degrees F and 95 per cent humidity for 4 hours. These results indicate that if a high relative humidity can be maintained where cut sets are stored, subsequent decay in the field can be held to a minimum.

Other greenhouse experiments indicated that size of set had but little to do with extent of decay. Large sets decayed just as badly and just as quickly as small ones.

SUMMARY

Experimental results indicate that potato seed piece decay in the field can be held to a minimum by proper handling methods. If sets are to be planted immediately after cutting, it is especially important that soil moisture be adequate for germination. If soil moisture content is low the sets are likely to dry out and decay quickly.

Potatoes should be cut and left in the storage cellar until just before planting. Excessive drying of the cut surfaces and subsequent rapid decay after planting will occur if sets are exposed for 3 hours or more to relatively high temperatures (60 degrees F or above) and low humidities (below 50 per cent). The longer the sets are exposed to such conditions the more likely they are to completely decay shortly after planting.

Simulated Hail Injury on Yellow Bermuda Onions[1]

By LESLIE R. HAWTHORN, *Texas Agricultural Experiment Station, Winter Haven, Texas*

ONIONS produced under irrigation in south Texas necessitate a relatively high investment per acre. After the grower has borne most of the production costs, the crop may still suffer serious injury from hail during March and April. Although hail occurs nearly every spring somewhere in the section, the area affected is usually limited, but the potential loss is so great that it is fairly common for some growers to reduce their risk by taking out hail insurance. Whether a hailstorm injures the bulbs of a nearly matured onion crop or not, it always injures the foliage. In a severe storm the foliage throughout large fields may be cut or pounded off entirely. Part of the present high cost of hail insurance is attributed to the lack of information on how much loss in the final yield of dry bulbs can be attributed to this loss of foliage. Also, adjustment in case of loss is often difficult because of a lack of understanding on the part of both grower and insurance adjuster as to the relationship between foliage injury and dry bulb yield. In an effort to gain some facts bearing on this problem, an experiment was conducted in the spring of 1943 at Substation 19, the Winter Garden Substation, of the Texas Agricultural Experiment Station to determine the loss in

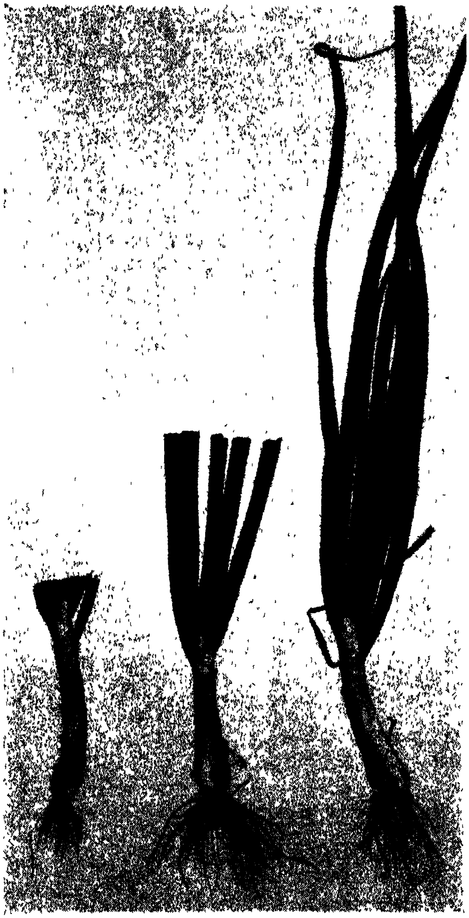

FIG. 1. Simulated hail injury in onion plants. Left, entire loss of foliage; center, half of foliage lost; right, uninjured check plant.

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[1] Approved by the Director as Technical Contribution No. 799 from the Texas Agricultural Experiment Station.

yield which might be due to the removal of definite amounts of foliage at intervals varying from 1 to 6 weeks preceding harvest.

The procedure described below did not go as far in imitating hail damage as the methods used by Knowles (4) and Eldredge (1, 2) both of whom worked with grain crops. While undoubtedly some of their procedures were definitely more imitative of hail than the one described here, it was thought more desirable in this preliminary work with onions to simulate hail injury simply by the removal of foliage.

PROCEDURE

A typical uniform field of Yellow Bermuda onions was selected, and starting in the last week of February or what later turned out to be 6 weeks before harvest, two treatments were made. In one, the entire foliage was cut off near the base of the lowest blades, a complete loss of foliage (Fig. 1). In the other, the foliage was removed at a point approximately one third of the way up the plant from the base of the lowest leaves; in this treatment half of the foliage was considered lost (Fig. 1). No records were taken to determine whether the loss of foliage in the second treatment was exactly 50 per cent or not. Since the basal portion of the leaf is larger than the tip portion, it is assumed that there is more leaf surface per linear inch of leaf towards the base than there is towards the tip, hence the removal of the foliage at the point indicated above is believed to approximate fairly closely a 50 per cent loss of foliage. Grass shears were used for the cutting.

Each treatment was carried out in four separate single-row plats of 100 plants each, and for every two treated plats there was an adjacent untreated one as a check. On the same day every week for 6 weeks a new series of plats was treated, so that by harvest-time there were 72 plats in all. The plats were all harvested on the same day, April 10, when 50 per cent or more of the tops in the check plats had fallen over or softened at the neck.

RESULTS

The yields recorded in Table I have been calculated from averages of the actual plat yields obtained in the various treatments. These

TABLE I—YIELD (BUSHELS* PER ACRE) OF ONIONS FROM WHICH ALL OR ONLY HALF OF THE FOLIAGE WAS REMOVED AT INTERVALS VARYING FROM ONE TO SIX WEEKS PRECEDING HARVEST

Number of Weeks Before Harvest that Removal of Foliage Occurred	Foliage Uninjured				Foliage Half Lost				Foliage All Lost			
	U. S. No. 1's		Culls	Total	U. S. No. 1's		Culls	Total	U. S. No. 1's		Culls	Total
	Jumbos and Mediums	Boilers			Jumbos and Mediums	Boilers			Jumbos and Mediums	Boilers		
6	505	23	12	540	309	46	23	378	112	87	31	230
5	606	14	14	634	311	35	18	364	99	80	35	214
4	491	17	16	524	289	40	27	356	133	49	24	206
3	441	21	23	485	231	52	34	317	137	50	46	233
2	506	22	19	547	293	50	18	361	241	56	24	321
1	437	29	29	495	422	25	42	489	349	36	28	413

*50 pounds per bushel.

figures indicate that the experiment was conducted in a field of productive onions and that losses of foliage in most instances caused considerable reduction in yield. However, because in any discussion of losses due to hail the chief interest of both the insurance adjuster and the grower is in the percentage loss, Table II has been prepared to show such losses. This table gives the percentage losses from the point of view of several different groupings: namely, U. S. No. 1 jumbo and medium sizes combined, U. S. No. 1 jumbo, medium and boilers combined, and the total yield including culls. The first of these groups represents those onions normally considered marketable under almost all conditions.

The amount of injury to the foliage was on the whole more important than the time at which it occurred. With the exception of several yields obtained from plants injured 2 weeks before harvest, there was always a significant difference between the yield resulting from a total loss of foliage, and that from only a half loss of foliage, irrespective of the time at which such injury occurred. A complete loss of foliage caused much greater losses in yield, even reducing the U. S. No. 1 yield by 20.1 per cent when the injury occurred only 1 week before harvest, while a 50 per cent loss of foliage at that time barely reduced the yield of bulbs below normal. In contrast, when the results from either treatment are considered alone, it is evident that there was comparatively little variation in the yields obtained as a result of injury 3, 4, 5, or 6 weeks before harvest. That is, there was rarely a significant difference between the results of adjacent weeks, although there was in general a gradual change so that one may occasionally find a significant difference between the yields of treatments two or more weeks apart. Removal of foliage in the fifth week before harvest caused the greatest percentage of loss in yield in both treatments. However, the differences between this and adjacent weeks were not always significant. A total loss of foliage occurring 3 to 6 weeks before harvest

TABLE II—THE PERCENTAGE LOSSES IN YIELD OF ONIONS CAUSED BY THE REMOVAL OF ALL OR ONLY HALF OF THE FOLIAGE AT INTERVALS VARYING FROM ONE TO SIX WEEKS PRECEDING HARVEST

Number of Weeks Before Harvest that Removal of Foliage Occurred	Half of Foliage Removed			Foliage Completely Removed		
	U. S. No. 1's		Total, including Culls	U. S. No. 1's		Total including Culls
	Jumbos and Mediums	Jumbos, Mediums, and Boilers		Jumbos and Mediums	Jumbos, Mediums, and Boilers	
6	38.8	32.8	30.0	77.8	62.3	57.9
5	48.7	44.2	42.6	83.7	71.1	66.2
4	41.1	35.2	32.1	72.9	64.2	60.7
3	47.6	38.7	34.6	68.9	59.5	52.0
2	42.1	35.0	34.0	52.4	43.8	41.3
1	3.4	4.1	1.2	20.1	17.8	16.6
Least Difference Necessary for Significance at 5 per cent level*	10.0	9.7	8.9	10.0	9.7	8.9

*These figures can also be used as a basis for testing the differences between percentages in corresponding columns. For example, one can compare percentage figures under the "Total" column where all the foliage has been removed, with those in the "Total" column where only half the foliage was removed.

reduced U. S. No. 1 yields of jumbo and medium onions by 68.9 to 83.7 per cent, or an average of 75.8 per cent, and the total yield from 52 to 66.2 per cent, or an average of 59.2 per cent. When this same injury occurred 2 weeks before harvest, the reduction in yield was less severe, and if it happened only 1 week before harvest, it was still smaller. Even then however the loss in U. S. No. 1 onions of jumbo and medium size amounted to approximately 20 per cent. With but half the foliage removed anywhere from 2 to 6 weeks before harvest, the U. S. No. 1 yields of jumbo and medium sized onions were cut 38.8 to 48.7 per cent, or an average of 43.7 per cent, and the total yields from 30 to 42.6 per cent, or an average of 34.7 per cent. When this injury occurred only 1 week before harvest, the loss in yield was statistically negligible (Table II and Fig. 2).

Percentages for the cull group by itself are not given in Table II because such figures would be misleading. As shown in Table I the yields of culls were usually very small and slight changes in them

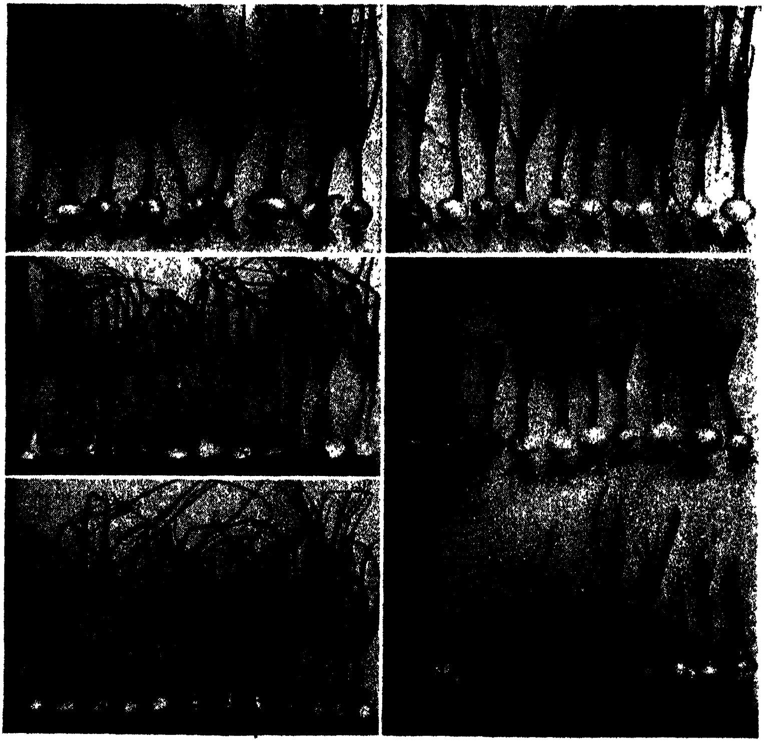

FIG. 2. Onions harvested at the same time. A and D, uninjured check plants; B and C, injured six weeks before harvest; E and F injured only one week before harvest; B and E, plants which lost half their foliage; C and F, plants which lost all their foliage. Note the undeveloped bulbs in B and C; both immature and mature bulbs (indicated by the presence or absence of new foliage) in F.

produced from one treatment to another can often be recorded only as very large percentages. For this reason the effect of the treatments on each of the various grades of onions is shown in Table III. The table brings out the fact that whether the foliage was entirely lost or only half lost, the percentages of culls, and with one exception those of the boilers also, were always increased, and the percentages of the U. S. No. 1 jumbo and medium onions correspondingly decreased. An entire loss of foliage always caused a greater reduction in the percentages of these two U. S. No. 1 sizes of onions than did the loss of only half the foliage. The increased percentages of culls and boilers although partly due to larger actual yields of these grades, was obviously nearly always chiefly due to greatly reduced total yields as shown in Table I.

TABLE III—PERCENTAGES OF THE TOTAL YIELD OF ONIONS FALLING IN THE VARIOUS GRADES AS A RESULT OF THE REMOVAL OF FOLIAGE AT INTERVALS VARYING FROM ONE TO SIX WEEKS PRECEDING HARVEST

Number of Weeks Before Harvest that Removal of Foliage Occurred	Foliage Uninjured			Foliage Half Lost			Foliage All Lost		
	U. S. No. 1's		Culls	U. S. No. 1's		Culls	U. S. No. 1's		Culls
	Jumbos* and Mediums	Boilers		Jumbos* and Mediums	Boilers		Jumbos* and Mediums	Boilers	
6	93.5	4.3	2.2	81.7	12.2	6.1	48.7	37.8	13.5
5	95.6	2.2	2.2	85.4	9.7	4.9	46.3	37.4	16.3
4	93.7	3.2	3.1	81.2	11.2	7.6	64.6	23.7	11.7
3	91.0	4.3	4.7	72.9	16.4	10.7	58.8	21.5	19.7
2	92.5	4.0	3.5	81.2	13.8	5.0	75.1	17.4	7.5
1	88.3	5.9	5.9	86.3	5.1	8.6	84.5	8.7	6.8
Least Difference Necessary for Significance at 5 per cent level	10.7	8.3	6.0	10.7	8.3	6.0	10.7	8.3	6.0

*Onions of jumbo size (over 3½ inches diameter) were nil or negligible in both treatments where the foliage had been injured. In the uninjured check plats the jumbos averaged 9.1 per cent of the total yield.

DISCUSSION

Analyses of variance for the data as a whole, as calculated for any of the grades given in Table II show significant differences at the 1 per cent level. This combined with the fact that the uninjured onions yielded so well and were representative of a good normal crop, would seem to warrant the conclusion that such data could be used at least tentatively as a basis for estimating reductions in yield due to losses in foliage from 1 to 6 weeks before harvest.

The effect of the foliage loss was both to retard and to reduce the development of the onions so injured. In this respect the results were not unexpected, in view of previous studies at this Station in which the removal of approximately half the foliage at transplanting time (16 to 18 weeks before harvest) had reduced yields (3). Hence for injured plants, greater percentages of the harvested bulbs fell in the boiler-size grade, and practically no bulbs at all were classified as jumbos (over 3½ inches diameter). In the uninjured check plats an average of 9.1 per cent of the total yield classified as jumbos. In some instances the cull grade was swollen by onions too small to classify as boilers, or by the type of bulb commonly known as "bottleneck". On the basis of unpublished data at this station, it might be claimed that the treated plats would have yielded more had the harvest been postponed. Such a procedure however would have defeated the purpose of this experiment, which was to determine the percentage of yield loss as based on a normal crop.

No data are given in the Tables to explain why the onions receiving treatment in the fifth week before harvest suffered the greatest percentage losses in yield. Supplementary notes indicated that it was in this week that the onions began to bulb. A possible explanation therefore is that at no other time either before or after bulbing starts, is the loss of foliage as serious as it is then. Supporting but not conclusive data for this supposition are: (a) In studies previously reported (3), yields were reduced only slightly by foliage removal as early as at transplanting time; and (b) In the present study, yield losses were less in the treatment made before bulbing began (sixth week) and in general progressively less as bulbing became more and more pronounced (from fourth through to the first week before harvest) than they were in the treatment made when bulbing was just beginning (fifth week before harvest). If future studies establish this supposition as a fact then insurance adjusters and growers may find it desirable to know both the date at which bulbing began, as well as the date when normal harvest would have occurred, for unpublished data at this station show that while there is considerable correlation between these two dates, the number of weeks between them may vary somewhat from year to year, as well as with the variety.

It should be kept in mind that the injury applied to the onions in this experiment was not actually caused by hail. Actual hail damage usually leaves the onion foliage in a more torn and pounded condition than does the simple procedure of cutting with shears. With hail, there would be more danger of complications from certain decay diseases. This possibility would be much more likely to occur if the hail storm were followed by several days of rainy weather. Observations made in onion fields injured by hail would indicate that if the weather clears, and dry conditions prevail, the danger from decay is greatly reduced. In the case of injury to the bulbs which is likely to happen with a hail storm occurring 1 or 2 weeks before harvest, there is a much greater danger from decay complications. Any injury to the bulbs necessitates a separate estimate of yield losses in addition to the one based on foliage injury. Such a loss is relatively easy to estimate however because the injury actually occurs to the marketable portion of the crop.

SUMMARY

A record of the percentage losses in yield sustained in various grades of Yellow Bermuda onions, when the foliage is either entirely removed, or when only approximately half of it is removed in each of the 6 weeks preceding harvest is given.

Except for the treatments made 2 weeks before harvest, there was always a significant difference between the loss of crop due to a complete removal of foliage and that due to the removal of only half the foliage. Yields of U. S. No. 1 jumbo and medium-sized onions were cut an average of 75.8 per cent by the complete removal of foliage 3 to 6 weeks before harvest. With the foliage removed 2 weeks ahead of harvest, the loss of yield in the same grade was 52.4 per cent, and if 1 week before harvest, only 20.1 per cent. Losses in total yields paralleled these just given, but were not as great.

From 2 to 6 weeks before harvest, the removal of half the foliage caused an average loss in the U. S. No. 1 yield of jumbo and medium sized onions of 43.7 per cent, and a corresponding average loss of 34.7 per cent in the total yield. Such injury only one week before harvest caused negligible loss.

Losses in U. S. No. 1 yields of jumbo and medium-sized onions as a result of foliage removal were chiefly due to the great reduction in total yield, rather than to the increase in yields of culls and boilers. The possible importance of the date when bulbing first begins is indicated.

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Louisiana Red Creole, a New Promising Onion Variety for Puerto Rico

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ABSTRACT

This paper will be published in detail in the *Journal of Agriculture*, University of Puerto Rico.

IT has been repeatedly shown by Garner and Allard (1), Magruder (2), McClelland (3), and Thompson and Smith (5) that length of day affects flowering and bulb formation in certain onion varieties. Most varieties, however, form bulbs with a rather long photoperiod and fail to form bulbs with a short photoperiod. Very few varieties are consequently adapted to the short photoperiod which prevails when onions are normally grown in the tropical latitude of Puerto Rico. At this latitude, 18° 12′, the length of day varies from 11 hours in December to 13.2 hours in June. The growing season for onions in this island extends generally from September to March when the shorter photoperiod exists. There is an adequate rainfall supply during the months of September, October, November and December which favors plant development, while the drier months of January, February, and March favor the maturing of bulbs. The dry months are also a limiting factor in the growing of onions due to heavy infestation of onion thrips (*Thrips tabaci* Lindemann) so common in dry weather.

Nolla (4) had tested the following varieties of onions in the northeastern corner of the island, at Fajardo: Red Bermuda, Yellow Bermuda, White Bermuda, White Crystal Wax, Australian Brown, Large Red Wethersfield, and Southport Yellow Globe. In his trials at that section bulbs were formed by the Bermuda varieties, White Crystal Wax, and Australian Brown.

Bearing in mind the previous work cited, preliminary trials with different onion varieties were started in the northwestern corner of the island, at the Isabela Substation, in the year 1939. The following onion varieties were included in these trials: Ebenezer, Australian Brown, Southport Yellow Globe, Southport White Globe, Ohio Yellow Globe, White Sweet Spanish, Riverside Sweet Spanish, Early Grano, Louisiana Red Creole, Yellow Bermuda and Red Bermuda. The Bermuda varieties were used as checks since they are the standard commercial varieties grown in the island. Seed from Louisiana Red Creole was introduced by Dr. J. A. B. Nolla, the director, and it bears in our records introduction number 45.

In these preliminary trials, Yellow Bermuda, Red Bermuda, Louisiana Red Creole, and Early Grano formed bulbs satisfactorily. While normal plant development was observed in all other varieties tested, they were a complete failure in regard to bulb formation.

Formal trials were then established with Yellow Bermuda, Red Bermuda, and Louisiana Red Creole. Early Grano was excluded due to a shortage of seed; however, a few seeds were available to plant a small plot for further observations. The period of planting was also extended so as to have information of yield when onions are not commonly grown in the region. The three varieties included in these trials were replicated five times and plots measured 1/200th acre approximately. Upon harvesting, the bulbs from each of the three varieties, were counted, classified and weighed accordingly.

The results of the two trials already harvested indicate a significant increase in yield of marketable onions with the variety Louisiana Red Creole when compared with the varieties Yellow Bermuda and Red Bermuda. Early Grano formed bulbs satisfactorily, but no yield records were taken due to the small area planted to this variety. The percentage of marketable onions by weight was as follows in the first trial: Louisiana Red Creole 97 per cent, Yellow Bermuda 87 per cent, and Red Bermuda 66 per cent. In the second trial percentages of marketable onions ran as follows: Louisiana Red Creole 98 per cent, Yellow Bermuda 91 per cent and Red Bermuda 84 per cent. The seed for

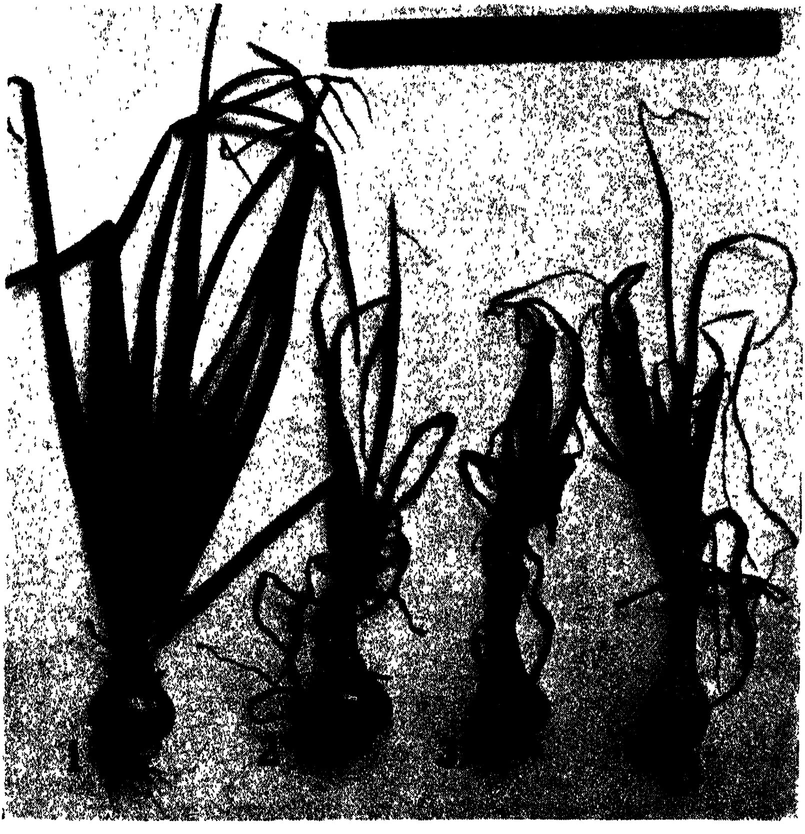

FIG. 1. The effect of the disease caused by *Macrosporium Porri* Ell upon different onion varieties. 1, Louisiana Red Creole; 2, Red Bermuda; 3, Yellow Bermuda; 4, Early Grano.

these two trials was obtained from the Kilgore Seed Company, Plant City, Florida.

During the month of December 1941 a disease was observed affecting seriously most of the onion varieties while still in the seed for the preliminary trials. However, it was also noticed that the variety Louisiana Red Creole seemed to show a remarkable resistance to this disease. In the month of April 1943, apparently the same disease was again observed in the field, when bulbs were beginning to mature. For the second time it was also observed that Louisiana Red Creole was showing a striking resistance to this disease which was affecting so seriously the foliage of the varieties Yellow Bermuda, Red Bermuda, and Early Grano. The effect of the disease upon the different varieties is shown in Fig. 1.

The causal organism of this disease has been identified by the phytopathologists Dr. J. A. B. Nolla and Mr. Luis A. Alvarez as being *Macrosporium Porri* Ell., synonym *Alternaria Alli* Nolla. Further trials should be established to confirm the apparent resistance to this disease by the variety Louisiana Red Creole. Nevertheless, the favorable results so far obtained with this new variety, indicate that it should be tried in other sections of the island in comparison with the Bermuda onions in order to verify this superiority under different climatic and soil conditions.

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The Effect of Spacing and Number of Plants per Hill on the Yield of Eleven Sweet Corn Hybrids

By J. L. Bowers, *University of Arkansas, Fayetteville, Ark.*

TRUCK crop growers in Arkansas have shown considerable interest in the production of sweet corn in recent years. The introduction of sweet corn hybrids has been partly responsible for the stimulated interest. The results of variety trials conducted during the last three years at various places in the state and the stimulated interest among the vegetable growers was partly responsible for this variety, spacing and thinning experiment. Work on spacing and thinning of sweet corn in the row has been done in Iowa, New York and Puerto Rico. Haber (1) in Iowa found that the largest ears were produced where there were only two stalks per hill. Bailey (2) came to the conclusion that soil and climatic conditions were vastly more important in influencing the yield per acre than were the spacings used in his experiment. At Geneva, New York, Enzie's (3) work showed that in some hybrids single plants spaced 9 inches apart in rows that were 30 inches apart produced higher yields than 36-inch checked rows. The larger hybrid types in the experiment at Geneva produced equally as good yields when spaced 30 inches apart in the row and thinned to three stalks per hill, as when spaced 9 inches apart in the row and thinned to a single stalk. His work on three different varieties definitely shows an interaction between spacing and the three different varieties studied. In 1942, spacing, thinning and variety tests were conducted at the main station at Fayetteville, Arkansas, in order to determine what varieties are adaptable to local conditions and what spacing and thinning in the row should be employed to obtain the maximum yield of marketable canning corn.

METHODS

The experimental lay-out consisted of four blocks of soil, each block 18 by 120 feet. In two of these blocks the hills were thinned to one stalk per hill, and the hills in the other two blocks were thinned to two stalks per hill. The thinning was done in such manner, so as to leave a latin square arrangement in effect. There were 39 rows in each block, each row spaced 3 feet apart. The three spacing treatments, hills 18, 24 and 36 inches apart in the row randomized within each block. Within each spacing plot (18 by 40 feet) the 11 varieties were randomized; a single row to each variety. Guard rows (non test rows) were planted between the different spacing plots. In a lay-out of this type the second order interaction, varieties by spacing by number plants per hill, was confounded with blocks.

The corn was planted April 1, after the rows had been accurately cross marked for the various spacings. After the plants were 6 inches tall, the hills were thinned according to the plans previously mentioned. The plots were cultivated frequently enough to control the weeds. The corn was harvested in the canning stage on four different dates, namely July 3, July 7, July 13 and July 20. It was graded according to

TABLE I—THE RESULTS OF ELEVEN SWEET CORN HYBRIDS, SPACED 18, 24, AND 36 INCHES APART IN THE ROW AND THINNED TO ONE AND TWO STALKS PER HILL (YIELD EXPRESSSED IN TONS OF U. S. NUMBER 1 CORN PER ACRE)

Varieties	Rate of Spacing						Rate of Thinning		Variety Yield
	Hills 18 Inches Apart in Row		Hills 24 Inches Apart in Row		Hills 36 Inches Apart in Row				
	1-Stalk	2-Stalks	1-Stalk	2-Stalks	1-Stalk	2-Stalks	1-Stalk	2-Stalks	
Deepcut	2.45	4.40	4.49	4.76	2 43	5.98	3.12	5.05	4.08
Golden Hickory Sweet	2.80	4.11	3.77	3.32	2.70	4.07	3.09	3.83	3.46
Aristogold Bantam Number 2	2.46	2.86	2.96	3.64	3.11	2.74	2.84	3.08	2.96
Iona	2.99	3.53	2.80	2.75	1.41	3.73	2.40	3.34	2.87
Ioana	2 18	2.72	3.18	2.22	1.56	4.94	2.31	3.29	2.80
Golden Hybrid	2.75	2.86	1.66	3.51	2.46	3.35	1 96	3 24	2.60
Goldgreen	1.24	2.90	3.12	2.11	2.39	3.42	2 25	2.81	2.53
Golden Cross Bantam	1.55	1.99	2.63	2.30	2.77	3.39	2.32	2.56	2.44
Silvercross Number 3	1.53	3.12	2.27	2.37	0.74	3.06	1.51	2.85	2.18
Lincoln Hybrid	2.27	1.83	1.91	0.63	2.22	1.98	2.14	1.49	1.81
Gold Rush Hybrid	0.25	0.27	0.56	0.37	0.91	0.29	0.57	0.31	0.44

standards set up for canning corn. The number and weight of ears were recorded in each grade.

RESULTS

The Golden Cross Bantam variety, which is most commonly grown in this region, was used as a standard to compare with the other hybrids. Two varieties, Deepcut and Golden Hickory Sweet, produced significantly more tonnage of marketable corn than Golden Cross Bantam. The difference in yield between these two leading varieties as shown in Table I is not significant. However, Deepcut produced significantly more tonnage than other varieties in the trial. The yields from Aristogold Bantam No. 2, Iona, Aristogold Bantam No. 1, Golden Hybrid, Goldgreen, Silvercross No. 3 and Lincoln Hybrid were not statistically different from the yield produced by Golden Cross Bantam. Gold Rush Hybrid variety produced a significantly lower yield than Golden Cross Bantam.

The yields from the treatment, hills thinned to two stalks, were significantly greater than the yields from hills thinned to one stalk. However, this was not the case in all varieties as shown in Table I. The varieties did not respond alike to the thinning treatment which is proven by a significant interaction between varieties and stalks in Table II. The yield of Deepcut, Golden Hybrid and Silvercross No. 3 were increased when each of these varieties were thinned to two stalks per hill instead of one stalk per hill. The difference between the two thinning treatments in the other varieties was not significant.

The number of stalks left in a hill did not produce the same response in the three spacing treatments of a variety, as shown by the significant interaction between spacing and stalks in Table II. This response appears to have a logical basis, because the feeding area of large growing hybrids might necessitate thinning to one stalk per hill in the close

TABLE II—ANALYSIS OF VARIANCE OF SWEET CORN YIELDS (YIELD EXPRESSED IN TONS OF MARKETABLE CORN)

Source of Variation	D/F	Total Sum Squares	S^2	F-Value	Required F-Value	
					05	01
Total	131	1486.2155	—	—	—	—
Blocks: Between Main Blocks	1	3.2179	3.2179	0.7102	3.96	6.96
Stalks	1	89.7930	89.7930	19.8187	3.96	6.96
Blocks ×Stalks	1	9.7390	9.6390	2.1274	3.96	6.96
Total	3	102.6499	34.2166	7.5521	—	—
Treatments: Varieties	10	639.2825	63.9283	14.1100	1.95	2.55
Spacing	2	16.8246	8.4123	1.8567	3.11	4.88
Variety ×Spacing	20	70.4518	3.5225	0.7774	1.70	2.11
Variety ×Stalks	10	102.0000	10.2999	2.2733	1.95	2.55
Spacing ×Stalks	2	70.7749	35.3875	7.8106	3.11	4.88
Error	84	380.5820	4.5307	—	—	—

Level of Significance		05	01
Difference required for significance	Between Stalks	0.30 ton	0.40
Difference required for significance	Between Varieties	0.70 ton	0.93
Difference required for significance	Between Varieties ×Stalks	1.04 ton	1.38
Difference required for significance	Between Spacing ×Stalks	0.52 ton	0.70

The second order interaction was confounded with Blocks and has been lumped with error.

spacing. While two stalks in a hill may have their feeding area requirements fulfilled in the wider spacing. The highest yield was obtained in Deepcut, Aristogold Bantam No. 1 and Golden Cross Bantam varieties when the hills were spaced 36 inches apart in the row and thinned to two stalks. In Aristogold Bantam No. 2, the treatment in which hills were spaced 24 inches apart and thinned to two stalks produced significantly higher yield than the other spacing and thinning combinations. In other varieties in this experiment there was no single combination of spacing and thinning which produced significantly higher yields than other combinations in the same variety.

CONCLUSION

Deepcut and Golden Hickory Sweet produced significantly more tonnage of canning corn than Golden Cross Bantam. The difference in yield between these two varieties was not significant. There were seven varieties, namely: Aristogold Bantam Number 2, Ioana, Aristogold Bantam Number 1, Golden Hybrid, Goldgreen, Silvercross Number 3, and Lincoln Hybrid, which produced yields that did not differ significantly from the yield of Golden Cross Bantam. Gold Rush Hybrid was the only variety that produced a definite inferior yield as compared with the yield of Golden Cross Bantam.

Effects of Moisture and Nitrate Concentrations on Growth and Bud Drop of Sweet Peas

By KENNETH POST, *Cornell University, Ithaca, N. Y.*

PREVIOUS investigations in soil and gravel culture (1) showed that the nitrate concentration in the media affected the growth and bud drop of sweet peas. High nitrate caused stunting, short stems, and reduced bud drop compared with low nitrate. It appears that any treatment of the plants which stimulates succulent growth increases bud drop.

Since soil moisture could be adjusted to regulate the succulency of growth these experiments were designed to find the effects of nitrate concentration and soil moisture on production and bud drop.

The plants were started from seeds which were inoculated with the legume organism and planted in sand the first week of August. Seedlings were transplanted to composted soil in waterproof ground beds which were 6 inches deep and equipped with tile for subirrigation. Each plot was 3½ by 5 feet, and two 5-foot rows of 25 plants each were placed in each plot. Each treatment was replicated twice with 5 feet of row for each of the varieties Lavender Harmony and Ball's Rose Improved in 1941–42 and with 10 feet of row of the variety Ball's White in 1942–43. All plants were grown with a high soil moisture content to stimulate vigorous growth until the first buds appeared and then the moisture and nitrate concentrations were adjusted. The temperature at night in the house was kept as low as possible during the late summer. After the out-of-doors night temperature lowered to 50 degrees F or less, the greenhouse was kept at 45 to 50 degrees F at night and 55 to 60 degrees F during the day.

A mercury soil tensiometer (2) was placed in the center of each plot so the top of the porous cup was level with the surface of the soil. The height of the mercury column was checked twice each day and water was added to the soil in the amount specified in the table. Water was applied by injecting it in the tile or surface watering as designated in the table. The water injected in the tile was measured through a water meter.

The soil in which the nitrate was to be kept low was mixed with one-fifth by volume of "Stays-Dry," a chopped sugar cane product. This reduced the soluble nitrate. During 1942 and 1943 a second application as a mulch was made to the surface of the soil after the soil was tested the first time because it was found to be higher in nitrate than desired. During the 1941–42 season nitrate of soda was applied from time to time to the high nitrate plots to keep the concentration as high as desired; in 1942–43, ammonium sulphate was applied.

The soil was tested for nitrate[1] by the phenol disulphonic acid method each two weeks, and nitrogen or sugar added to increase or decrease the nitrate after the test showed it to be lower or higher than desired. The Spurway quick test (3) was used for testing for potash, calcium and phosphorous each month and the glass electrode used for determining pH. Phosphorous remained from 8 to 20 parts per million, potash between 15 and 40 and calcium near 150, ranging from 100 to 200 parts per million. The pH was about 6.8 to 7.1. The high nitrate plots averaged from .1 to .3 higher in pH than the low nitrate plots. Table I shows the variability of nitrate during the period.

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[1] John Seeley and Joseph Howland of the department tested the soils.

TABLE I—AVERAGE NITRATE CONCENTRATION (PARTS PER MILLION) OF SOIL EXTRACT

Date	High Nitrate	Low Nitrate	Date	High Nitrate	Low Nitrate
	1941–42			*1942–43*	
Aug 15	70 ±7.7*	51 ±4.8	Oct 7	42.1 ±3.88	12.6 ±1.35
Sep 2	57 ±11.7	33 ±1.4	Oct 21	71.3 ±3.51	23.6 ±4.22
Sep 16 ..	76 ±7.9	29 ±3.9	Nov 7	89.3 ±6.12	24.1 ±3.69
Oct 1 ..	71 ±9.9	15 ±2.6	Nov 21	77.1 ±9.10	4.0 ±0.47
Oct. 16	104 ±10.1	24 ±0.7	Dec 6	97.1 ±6.76	5.2 ±0.69
Nov 1 .	131 ±11.6	11 ±1.3	Dec 17	94.6 ±6.88	5.2 ±0.34
Nov 15	130 ±10.2	6 ±1.6	Jan 1	110.0 ±3.24	4.9 ±0.65
Dec 1 ..	148 ±9.2	7 ±0.8			
Dec 15	142 ±8.4	6 ±1.3			

*Probable error by Bessel's-formula.

The high and low nitrate plots were arranged on each of the four moisture treatments. This made it possible to calculate the high and low nitrate regardless of the moisture treatment and to calculate the various moisture treatments regardless of the nitrate. Thus there were seven high and seven low nitrate plots and four each of the moisture treatments excepting the surface watered plots which were in duplicate only.

During the experiment the object in 1941 was to keep the high nitrate plots between 100 and 150 parts per million and the low nitrate below 10 parts per million. During 1942 the attempt was to keep the high nitrate plots between 75 and 100 parts per million and the low nitrate near 5 parts per million. Table I shows the approximation to these concentrations and both years the plots reached the desired concentrations during November.

Flowers were picked starting during November and continuing through January but the greatest production was during December and January which was after the nitrate adjustments had been made. Adjustments of nitrate and water were not made earlier than when flowering started because of the effect on growth. It had been found previously that high nitrate or low water gave hardened plants if started with seedlings. We desired to determine the effect of the adjustments which could be made after vigorous succulent vines were available.

The results given in Table II show the effect of nitrate concentration and moisture supply on production, stem length, and bud drop. The trend is for the greater production with low nitrate. This also gave greater stem length and greater bud drop. The bud drop and stem length data are significant or nearly so, but the production is not significantly different.

The trend was for more production, shorter stems and less bud drop with less water but these differences are not significant. Previous

TABLE II—EFFECTS OF NITROGEN CONCENTRATION AND WATER

Treatment	Salable Stems Produced	Average Length of Stems (Inches)	Number Salable Stems For Each Stem With No Buds
	1941–42—5 Feet of Row		
High nitrate	283.1 ±12.34	10.69 ±0.14	6.11 ±0.70
Low nitrate	319.3 ±10.45	11.78 ±0.11	3.95 ±0.44
	1942–43—10 Feet of Row		
High nitrate	425.1 ±40.83	10.9 ±0.36	5.81 ±1.11
Low nitrate	438.9 ±37.77	11.5 ±0.37	3.09 ±0.45
	1941–42—Water Treatments—5 Feet of Row		
Saturate at 3 cm tension	277.1 ±11.26	11.68 ±0.25	3.45 ±0.55
0.5 cu ft at 3 cm tension	309.4 ±18.75	11.52 ±0.19	3.79 ±0.79
Surface at 25 cm tension	312.5 ±22.45	11.04 ±0.47	6.31 ±1.85
0.5 cu ft at 20 cm tension	311.4 ±17.00	10.60 ±0.22	7.22 ±1.41
	1942–43—Water Treatments—10 Feet of Row		
Saturate at 3 cm tension	345.5 ±53.55	11.6 ±0.42	2.16 ±0.41
0.5 cu ft at 3 cm tension	432.5 ±12.20	11.5 ±0.53	3.07 ±0.31
Surface at 25 cm tension	316.0 ±51.26	11.5 ±1.08	7.16 ±5.90
0.5 cu ft at 20 cm tension	576.0 ±46.27	10.4 ±0.17	6.76 ±0.86

experiments have clearly shown these differences to be extreme when treatments are started with young plants. It is evident the effect is of little consequence when water and nitrate are adjusted starting at the time of flowering.

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Effect of Sulphur Particle Size and of Aluminum Sulphate on Rate of Soil Acidification

By J. C. RATSEK, *Texas Agricultural Experiment Station, Tyler, Tex.*

SULPHUR PARTICLE SIZE

SULPHUR for soil acidification is obtainable commercially in a number of different particle sizes from 8 mesh to 325 mesh. The coarser mesh sulphurs are less expensive per pound but are slower in rate of oxidation and therefore of soil acidification. An effort was made to determine the best mesh sulphur to be used for soil acidification from the standpoint of both cost and efficiency.

A black waxy calcareous prairie soil of the San Saba series was permitted to dry out thoroughly. It was then crushed and sifted through a 16-mesh screen. After mixing thoroughly, eighteen 30-pound lots were weighed up and mixed as follows:

1. Soil alone — check
2. Soil plus 8 ounces 8-mesh sulphur
3. Soil plus 8 ounces 16-mesh sulphur
4. Soil plus 8 ounces 32-mesh sulphur
5. Soil plus 8 ounces 325-mesh sulphur plus 4 ounces of a neutral balanced mixture of ammonium sulphate and sodium nitrate.

Three lots of each were thoroughly mixed and placed in 3-gallon glazed crocks on July 8, 1942. Because of lack of greenhouse space crocks were not watered until July 31. On this date and at irregular intervals thereafter pH readings were made with a Quinhydrone electrode.

Fig. 1 records the average pH reading of the various treatments. A difference of .099 in pH is significant. The 8-mesh sulphur while cheapest was somewhat slow to oxidize. There was no appreciable difference between 16- and 32-mesh in rate of oxidation whereas the 325-mesh is somewhat faster. For all practical purposes it would seem that when cost and rate of oxidation are both considered the 16 mesh sulphur is the best for use as a soil acidifier. It is to be understood that sulphur of a given mesh contains no particles larger than the indicated mesh; that is, 8-mesh. It does, however, include all smaller particles, many as small as a micron or less in diameter.

Of interest was the very rapid rate of oxidation of the sulphur when an excess of nitrogen was present. The nitrogen is necessary for the rapid multiplication of the sulphur oxidizing bacteria. The greater the number of bacteria the more rapid the rate of soil acidification. It would seem that a mixture of sulphur and ammonium sulphate would be even more efficient and will be worth further study.

ALUMINUM SULPHATE VS. SULPHUR

Considerable disagreement is evident in the literature as to the relative efficiency of sulphur and aluminum sulphate as soil acidifiers.

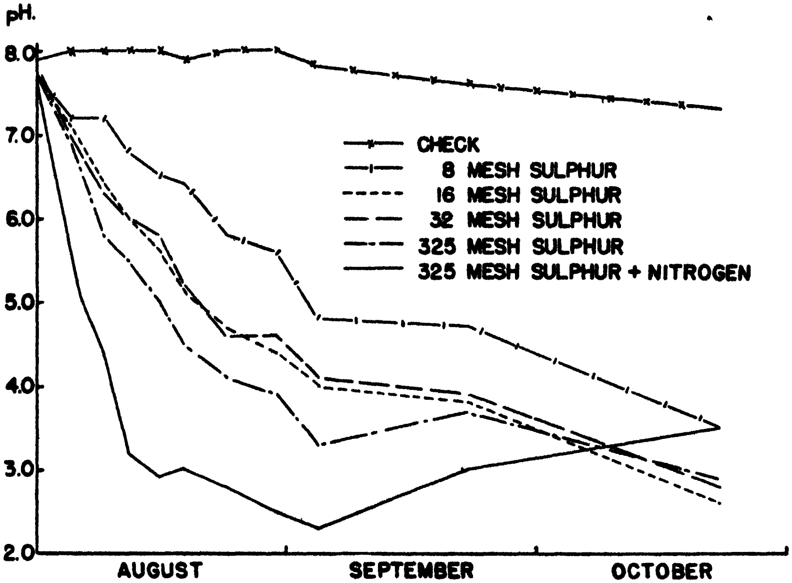

FIG. 1. Effect of particle size and nitrogen on rate of oxidation of soil sulphur.

In making recommendations for the use of these two commonly used materials some writers recommend the use of 1 pound of sulphur or 3 pounds of aluminum sulphate. Other writers may recommend a ratio of 1 pound of sulphur to 7 pounds aluminum sulphate.

To get more accurate information on this problem an experiment was set up similar to the one above. Twenty-five pounds of soil were used in each crock. Three of each of the following mixtures were prepared June 9, 1942:

1. Soil — check
2. Soil + ¼ pound 16-mesh sulphur
3. Soil + 1¾ pounds aluminum sulphate
4. Soil + 1¼ pounds aluminum sulphate
5. Soil + ¾ pound aluminum sulphate
6. Soil + ¼ pound aluminum sulphate

This series provided for test ratios of 1 : 1, 1 : 3, 1 : 5, and 1 : 7 sulphur and aluminum sulphate respectively. Early in the study it was evident that there was too much acidifier for the lime and this resulted in a bunching together of the three higher aluminum sulphate treatments and of the sulphur treatments. To widen the interval between the various treatments soil was watered with water with a pH of 8.2 at irregular intervals beginning June 25. The pH reading of these three treatments still remained relatively low so after the September 15 reading was taken, the soil was permitted to dry out until November 1. At this time the soil in each crock was screened through a 16-mesh screen and mixed with 4 ounces of hydrated lime. All water added to the soil was pH 8.2 and was added in equal amounts to each crock.

The results are indicated in Fig. 2. A difference of .22 pH is necessary for significance at the 1 per cent level. Sulphur while slower than aluminum sulphate was able to acidify soils as much or more so than seven times its weight in aluminum sulphate. Sulphur carried the pH of the soil lower than aluminum sulphate which seemed to reach an equilibrium depending upon the amount used as well as the amount of lime present. When equilibrium is reached the soil seems to be somewhat buffered against rapid pH fluctuations.

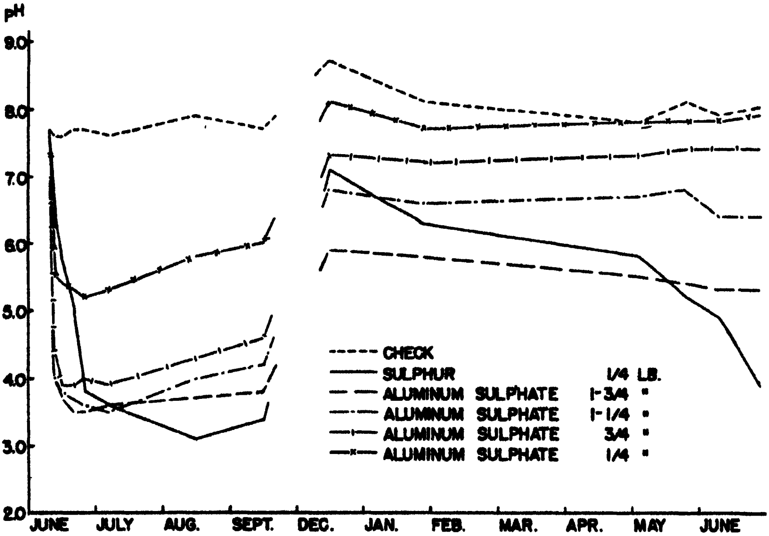

Fig. 2. Effect of sulphur and of aluminum sulphate on rate and degree of soil acidification.

The graph explains the wide differences in opinion as to the relative amount of sulphur or aluminum sulphate to use. A single determination made on June 20, June 25, August 15, or on December 15, would permit of a variety of conclusions three of which would be erroneous. A pH determination made between June 13 and 20, would indicate that 1 pound of sulphur would acidify soil to the same degree as 1 pound of aluminum sulphate. A determination made from June 15 to September 15 would lead to the conclusion that 1 pound of sulphur is equal in acidifying action to 7 or more pounds of aluminum sulphate.

Summary

Sixteen mesh sulphur was found to be the best for use as a soil acidifier. The presence of an excess of nitrogen greatly hastened the rate of oxidation of sulphur in the soil. One pound of sulphur will acidify a given volume of soil to the same degree as 7 or more pounds of aluminum sulphate.

Factors Influencing the Germination of Iris Seed and the Relation of Inhibiting Substances to Embryo Dormancy[1]

By L. F. RANDOLPH and LELAND G. COX, *Cornell University, Ithaca, N. Y.*

THE delayed germination of iris seed is a problem of major importance to iris breeders and others interested in growing iris from seed. The seed is ordinarily planted in the autumn soon after it is harvested and germination of a certain proportion of the seed may take place the following spring or thereafter at yearly intervals for several years. The number of seedlings obtainable during the first or second year from different samples of seed is extremely variable. Sir Michael Foster (5), pioneer iris hybridizer, stated in 1924 that in his experience, extending over many years, relatively few seeds germinate the first year after planting, rather more germinate the second year and thereafter a few more seeds germinate yearly for from 5 to 15 years. In his experience seeds that had remained dormant in the seed bed for 18 years were still sound and apparently viable.

The physiology of dormancy in iris seed has not been investigated extensively. Crocker (3) reported that germination could be induced in dormant seeds of *Iris sibirica* and *I. pseudacorus* by removing the cap of tissue covering the radicle in the region of the hilum. It was stated that this chipping of the seeds caused the embryo to elongate from 3 to 7 millimeters within 24 hours, and germination was said to be completed in 97 per cent of the seeds within 20 days. Crocker believed that germination of the intact seed was prevented by mechanical forces exerted by the tissues surrounding the embryo, since soaking in water caused a swelling of the embryo, which, however, failed to germinate unless the radicle was exposed. The results obtained by Crocker have not been confirmed by other investigators.

A significantly higher germination was obtained by Arceneaux (1) from immature seeds of *Iris giganticoerulea* stored in moist soil at a relatively high temperature than was obtained from mature seed given no special treatment. Storage for 71 days at 27 to 35 degrees C resulted in 81 to 87 per cent germination within 6 months after treatment.

Germination records extending over a period of 12 years were published by Essig (4) together with an account of various experiments designed to induce more rapid and complete germination of the seed of garden varieties of bearded iris. During this 12-year period 14,400 seedlings were obtained by Essig from 36,890 seeds, the seed planted each year being retained in the seed beds for 2 years. This is an average of 39 per cent germination. The procedure followed by Essig was to plant the air-dried seeds within a few weeks after harvest.

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[1] Cooperative investigation of the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture, and the Departments of Botany and Floriculture and Ornamental Horticulture, New York State College of Agriculture, Ithaca, New York.

More seedlings ordinarily were obtained the first year than the second, although in certain instances the reverse was true. The number of seedlings obtained after the second year was not sufficient to warrant the maintenance of the seed beds for a longer period of time. In experiments performed by Essig germination was not improved by chipping the seeds, by prechilling at 38 to 42 degrees F for 2 to 4 weeks before planting, or by planting the freshly harvested undried seed. Weak doses of X-rays were also utilized without success in an attempt to break the dormancy of the seed.

Werckmeister (7) reported that the embryos of normal iris seed and abnormal seed with poorly developed endosperm, obtained by intercrossing varieties with different chromosome numbers, could be cultured on a nutrient medium consisting of Pfeffer's solution plus agar and 0.5 per cent glucose and levulose. Seedlings were obtained from both freshly harvested and dried seeds, but a very limited number of individuals apparently were involved in the experiments.

Germination of Seed Under Field Conditions

The following data on the germination of iris seed under field conditions at Ithaca, New York, were obtained during the 4-year period from 1938 to 1941, in cultures originating from crosses between either tetraploid or diploid garden varieties of bearded iris (Pogoniris). The seed of triploid or pentaploid varieties and the seed obtained from intercrosses between different members of a polyploid series ordinarily germinates poorly and the data from such crosses were not included in this summary.

TABLE I—Data on Germination During the First Year After Planting of Iris Seed Obtained from Controlled Pollinations During the 4-Year Period from 1938 to 1941

Year	Seeds Planted	Seedlings Obtained the Following Year	Per Cent Germination	Number of Cultures
1938	3164	638	21	28
1939	3242	652	22	33
1940	2068	811	39	14
1941	3985	2234	56	50

The average germination during the first year of these 125 cultures, which included a total of 4335 seedlings from 12,459 seeds, was 35 per cent. In these trials the seed was air-dried each year as soon as it was harvested and planted in carefully prepared seed beds in garden soil within 3 to 4 weeks after harvest. No winter cover was provided and the seed beds were subjected to alternate freezing and thawing during the winter months. In 1940 and 1941 the seed beds were kept more thoroughly watered during the period when germination was in progress in late April and May than in preceding years and this may have been responsible for the somewhat increased germination obtained in these years.

The data reported in Table I are for 1-year periods from the time of planting. If the germination during the second year were included the percentage germination ordinarily would be increased from 10 to 15 per cent. For example, 652 seedlings were obtained in 1940 from 3242 seeds planted the previous year, and an additional 286 seedlings were obtained in 1941. However, the relatively high percentage of germination obtained in 1942 from the 1941 crop of seed was followed by very little additional germination in 1943. Of the 1751 seeds which failed to germinate in 1942 only 36 or 2 per cent germinated in the spring of 1943.

The seed of certain crosses germinated very well while that of other crosses germinated very poorly. The best germination obtained from the seed of any one of the 125 crosses during the 4-year period was 76 per cent, but many samples gave less than 10 per cent germination, and some fairly large samples of apparently good seed failed to germinate at all. The seed of crosses that germinated poorly the first year in some instances germinated much better the next year and, conversely, few additional seedlings ordinarily were obtained the second year from crosses that germinated well the first year. In one particular cross, 100 seeds obtained in 1939, and planted in the fall of that year produced 7 seedlings in 1940 and an additional 51 seedlings in 1941; another cross made the same year produced 142 seeds of which 47 germinated the first year, but only 3 germinated the second year. The response to uniform environmental conditions favorable to germination of fully mature and sound samples of seed from various crosses was so very different that it is highly probable genetical differences were responsible for this lack of uniformity in germination.

The results of the germination trials at Ithaca, New York, from 1938 to 1941 agreed closely with the data reported earlier from California by Essig. This suggests that the diverse climatic and soil conditions of these two regions had relatively little effect on dormancy in iris. In both localities less than 50 per cent of the seed germinated within two years after planting.

In an effort to improve the germination of iris seed various experiments of an exploratory character were performed over a period of several years beginning in 1938. For these experiments a quantity of mature, open-pollinated seed was collected each year from numerous garden varieties growing in the breeding plots. After being thoroughly air-dried the seed was stored at room temperature in a dry place until ready to use, except in certain experiments involving freshly harvested seed. Tests of various physiological factors that might reduce the period of dormancy, included drying for various periods of time, variations in storage temperature, germination in media of different hydrogen ion concentration, exposure to light, removal of the endosperm, chipping, leaching and increased oxygen pressure. In view of the rather limited supply of seed suitable for experimentation, the number of individuals involved in some of the experiments was not adequate to distinguish relatively slight, significant differences between treatments.

LOW-TEMPERATURE STORAGE OF MOIST AND DRY SEED

Seed that had been air-dried for 4 to 6 weeks after harvest was placed in dry storage at —2 degrees C, 0 degree and 4 degrees C for various period of time, ranging from 2 to 12 weeks. Similar lots were stored in moist sand at these same temperatures and for the same periods of time. As a control experiment, additional samples were placed in wet and dry storage at room temperature ranging from 20 to 25 degrees C for the same intervals of time. After treatment, the seed was planted in the greenhouse and the total number of seedlings produced by each sample was recorded 8 months after the termination of the individual treatments. These data are summarized in Table II.

TABLE II—Germination Percentages Obtained from Wet and Dry Iris Seed Stored at Various Low Temperatures for Different Periods of Time

Weeks Treated	Per Cent Germination Following Various Conditions of Storage*							
	-2 Degrees C		0 Degree C		4 Degrees C		20 to 25 Degrees C	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
2	12	17	19	14	18	16	16	13
4	31	27	26	25	27	26	12	14
6	26	32	28	22	25	19	20	18
8	28	23	25	29	23	23	17	15
12	32	27	29	26	32	29	13	12

*Average for 2 week treatments at -2 degrees C, 0 degree C, 4 degrees C; wet 16 per cent; dry 17 per cent. Average for 4 to 12 week treatments at -2 degrees C, 0 degree C, 4 degrees C; wet 28 per cent; dry 26 per cent. Average for controls, held for 2 to 12 weeks at 20 to 25 degrees C, wet 19 per cent; dry 16 per cent.

Low temperature storage for periods shorter than 2 weeks had no appreciable effect on the final germination percentage but storage at —2 degrees C, 4 degrees C for periods of 4 to 12 weeks did have a beneficial effect which was apparently independent of the temperature within the range of —2 degrees to 4 degrees C. Wet storage combined with low temperatures increased the rate of germination as compared with dry storage, but the final percentage germination was the same. The results indicate that wet storage at low temperatures increases the rate of after-ripening and also increases the final germination percentage. Dry storage at low temperatures does not increase the rate of after-ripening, but does increase the final germination percentages as compared to dry storage at room temperature. Apparently, at low temperatures, both moist and dry seed from recently harvested samples undergo a conditioning process which greatly increases their ability to germinate. The low temperature behavior of both freshly harvested undried seed and air-dried seed is now being investigated in order to get a further insight into this conditioning process.

High Temperature Treatment of Moist and Dry Seed

Dry seeds which had been stored at room temperature for 4 months were placed in an electric incubator maintained at a constant temperature of 35 degrees C for a period of 3 weeks, one sample of dry seeds being placed in paper packets and another comparable sample being placed on moist filter paper in petri dishes. At the end of the treatment the treated seeds were planted in the greenhouse together with similar untreated seeds to serve as a check. Each sample contained 60 seeds. Within 3 months after the termination of the experiment, 40 per cent of the moist seeds that had been subjected to the high temperature treatment had germinated; only 3 per cent of the dry seeds similarly treated had germinated. Twenty-seven per cent of the untreated seeds germinated during the same period. All but 2 of the 24 seedlings produced by the moist seeds appeared within 2 months after the termination of the heat treatment. Thus it would appear that there was ample time for the treated dry seeds to have germinated if their ability to germinate had not been adversely affected by the treatment.

Alternating Low and Moderate Temperatures

The effect on dormancy of exposing moist iris seed alternately to low temperatures and temperatures favorable to germination was determined in a series of experiments undertaken in January 1939. Seed that was harvested in August 1938 and placed in dry storage at room temperature after being thoroughly air-dried in sunlight was planted in moist sand in petri dishes. In one experiment 100 seeds were subjected to near-freezing temperatures and sub-freezing temperatures from +5 degrees to —15 degrees C for 1 week, then returned to a temperature of 25 degrees C for 1 week, this alternation of temperatures at weekly intervals being repeated four times beginning January 10, 1939. The seeds were then transferred to a greenhouse in which the temperature ranged from 15 to 25 degrees C. In another experiment seeds were subjected alternately to temperatures of 4 degrees C and 25 degrees C every 2 days. Some of the seeds to be treated were placed in wet sand, others were placed in garden soil and still others in shredded peat. The acidity of these media ranged from a pH to 4.10 for the peat to 8.55 for the sand, with an intermediate value of 5.65 for the soil. Fifty seeds were transferred from each of the media to the greenhouse after 4, 8, 12, 16, and 20 alternate treatments. The number of seedlings was recorded at monthly intervals for each sample in both experiments. At the end of 4 months when germination had ceased it was apparent that none of the treatments had appreciably increased the percentage germination of the seed above the values obtained for continuous low temperature treatments of 4 or more weeks, as reported in Table II.

Effect of Media Differing in Hydrogen Ion Concentration

An additional test of the possible effect of hydrogen ion concentration on germination of iris seed was made by planting 100 seeds in each of the three media described in the preceding experiment, namely peat, soil and sand, their pH values being respectively 4.1, 5.6 and 8.5. After being planted the seeds were subjected to low temperatures ranging from 0 degree to —10 degrees C for 1 month and then transferred to the greenhouse. Approximately the same number of seeds germinated in each medium, the actual percentages being 28 for the peat, 25 for the soil and 32 for the sand. This experiment, and the preceding experiment which involved alternating temperatures in addition to differences in the acidity of the medium, indicated that the use of media of different hydrogen ion concentrations within the range ordinarily encountered in the germination of seeds has no pronounced beneficial or harmful effect on the germination of iris seeds.

EFFECT OF LIGHT ON GERMINATION

Samples of freshly harvested seed were dried for 10 days in the sunlight and in the dark at 30 degrees to 35 degrees C and then planted in the usual manner with no significant difference in the number of seedlings obtained the following spring.

Another sample of freshly harvested seed was dried in the sunlight for several days and then scattered in shallow trenches and left uncovered for one month, during which period they were watered frequently to prevent excess desiccation. They were then covered with moist soil in the usual manner. A similar sample of seed was treated in the same manner except that it was covered with soil immediately after being planted. The following spring 12 per cent of the light-treated seeds produced seedlings as compared with 28 per cent from the seeds planted in the usual manner.

In another experiment to eliminate the retarding effect of desiccation, seed that had been dried in sunlight and then stored air-dry for 2 months were planted on moist sand beneath a sheet of glass to retard evaporation and fully exposed to light at 16 degrees to 30 degrees C for 2 months with no evidence of germination. Covering the seeds with soil and subjecting them to near-freezing temperatures for 1 month, however, yielded 30 per cent germination after 6 weeks in the greenhouse. In the control experiment, seeds covered with soil and subjected to the same series of treatments yielded 32 per cent germination.

The results of these experiments failed to support the prevalent view that the drying of freshly harvested seed in sunlight has a beneficial effect on germination.

EMBRYO CULTURE AND THE RELATIONSHIP OF THE ENDOSPERM TO EMBRYO DORMANCY

Permeability relations of tissues enclosing the embryo were eliminated as possible factors inhibiting germination in an experiment in which the intact embryos were removed from the seed and cultured on nutrient agar under aseptic conditions, or the seed was cut in half to expose the embryo lying in contact with the endosperm. This experiment also served to test for the presence of substances surrounding the embryo which inhibit germination. Previous experiments of Cox (2) and others have demonstrated the existence of such inhibiting substances in various seeds.

One hundred fifty seeds were soaked for 24 hours in tap water at 26 degrees C to facilitate the excision of the delicate embryo from the cavity at the micropylar end of the seed. The seeds were then sterilized for 2 hours in a saturated aqueous solution of calcium hypochlorite (8) and divided into three lots, each containing approximately 50 seeds. One lot was left intact to serve as a control, the seeds of another lot were sectioned longitudinally to expose the full length of the embryo lying in the cavity of the endosperm; the embryos of the third lot of seeds were completely excised. The intact seeds, those sectioned longitudinally to expose the embryos and the excised embryos of the third lot were transferred individually under aseptic conditions to 1-ounce, screw cap bottles containing 10 cubic centimeters of sterile nutrient agar.

The nutrient agar medium was prepared by dispersing 7 grams of agar in 1 liter of boiling distilled water. After the agar was completely dispersed 20 grams of C.P. sucrose were dissolved in the hot solution of agar and 5 cubic centimeters of each of the following two nutrient solutions were then added.

Solution A

$Ca(NO_3)_2 \cdot 4H_2O$	23.6 grams
KNO_3	8.5 grams
KCl	6.5 grams
H_2O	500 cubic centimeters

Solution B

$FeSO_4 \cdot 7H_2O$	0.2 grams
$(NaPO_3)n$	1.0 gram
$MgSO_4 \cdot 7H_2O$	3.6 grams
H_2O	500 cubic centimeters

Solution B was prepared by dissolving the $(NaPO_3)n$ (Calgon unadjusted) in 250 cubic centimeters of distilled water. The $FeSO_4 \cdot 7H_2O$ and $MgSO_4 \cdot 7H_2O$ were likewise dissolved in 250 cubic centimeters of distilled water. The two solutions were then mixed to form the final solution B. If either solid $(NaPO_3)n$ or $FeSO_4 \cdot 7H_2O$ is added to a solution of the other salt an insoluble precipitate is formed.

Solution B is stable for indefinite periods of time at room temperature, but as a precaution against the decomposition of the hexametaphosphate to form insoluble precipitates of iron phosphate the solution is stored at 4 degrees C. Attempts to sterilize solution B in the autoclave have resulted in the formation of a dense precipitate of iron phosphate.

The nutrient agar medium prepared in this manner had a pH of 5.9 to 6.3 following sterilization for from 15 to 30 minutes in the autoclave.

For small numbers of bottles sterilization for 15 minutes at 15 pounds of steam pressure was found to be sufficient, but for large numbers of bottles, particularly when the bottles are closely packed together, sterilization for 25 minutes is necessary in order to kill certain anaerobic spore-forming bacteria. Sterilization for periods longer than 25 minutes may cause partial hydrolysis of the agar.

Granular $(NaPO_3)n$ or sodium hexametaphosphate was used as a source of phosphate since it forms a soluble complex with both iron and calcium to produce a perfectly clear nutrient agar in which both the iron and calcium phosphate remain in solution for indefinite periods of time.

The 1-ounce screw-cap bottles were similar to those recommended by Tukey (6) with the exception that the waxed paper and cardboard retainers were removed to facilitate gas exchange. No more than two embryos were placed in each bottle in order to limit the spreading of contaminations and to insure adequate aeration of the developing seedlings.

Following excision, the 150 bottles of seeds and embryos were transferred to the diffuse light of a fernery shaded by double layers of cheesecloth. The diffuse light was sufficient for chlorophyll formation and photosynthesis but prevented injury to the delicate growing point by direct exposure to sunlight. After 10 days in the diffuse light, leaf and root development of the completely excised embryos were taking place at a rapid rate and the bottles were then transferred to direct light in the greenhouse where the maximum daily air temperature was approximately 90 degrees F. The direct light and higher temperature stimulated rapid leaf development along with an extensive and well branched root system suitable for transplanting.

At the end of 41 days all germinated seed and embryos were transferred to a sterilized potting mixture of sand and compost in 2-inch, sterile clay pots. After being placed in a cool orchid house at a high humidity and in diffuse light for 1 week the transplants were brought back to the greenhouse under conditions suitable for optimum growth.

The germination behavior of the intact seed, embryos in contact with the endosperm and completely excised embryos are summarized in Table III. In the initial stages of the growth of the embryo, elongation accompanied by geotropic bending of the radicle was taken as an index of germination.

TABLE III—GERMINATION OF INTACT SEED, EMBRYOS IN CONTACT WITH ONE-HALF OF THE ENDOSPERM AND COMPLETELY EXCISED EMBRYOS OF IRIS DURING A PERIOD OF 41 DAYS

Days	Percentage Germination		
	Intact Seed	One-Half Endosperm	Excised Embryo
3	0	21.7	57.2
5	0	21.7	84.0
6	0	41.3	94.6
41	18.7	45.7	94.6

Germination of the excised embryos produced normal symmetrical seedlings, but the exposed embryos in intimate contact with endosperm tissue developed slowly and were often markedly deformed. However, in certain instances the elongating embryos pushed away from close contact with the endosperm and thereafter grew at a more rapid rate, comparable to that of the completely excised embryos. Among the developing seedlings that remained in intimate contact with the endosperm, inhibition of growth was apparent in the radicle and secondary roots, and the primary seedling leaves were likewise limited in growth and deficient in chlorophyll.

In the initial stages of development the excised embryos grew more rapidly than did those of the intact seed or those in contact with endosperm tissue, but this situation was later reversed. At the end of 83 days seedlings originating from the intact seeds averaged 11.23

centimeters in height, those derived from embryos in contact with a portion of the endosperm averaged 9.82 centimeters and those from excised embryos were 6.97 centimeters in height.

During the later stages of development the inhibiting effect of the endosperm tissue is apparently overcome by the developing seedlings which then make efficient use of the reserves in the endosperm tissue to supplement food materials furnished by the nutrient medium and by photosynthesis.

From this experiment it was concluded that the endosperm tissue of the iris seed definitely inhibits the germination and early growth and development of the seedling. This inhibition extends to all parts of the seedling, including the primary seedling leaves and chlorophyll formation. The degree of inhibition is greatest in intact seed where there is no opportunity for the dormancy-inducing factor to diffuse out into the adjacent medium or to be inactivated by the metabolic activity of the embryo or by atmospheric oxygen. The rate of growth of the seedling after the inhibiting materials have disappeared is in direct proportion to the amount of endosperm tissue present. Thereafter, the reserve materials in the endosperm play an active role in growth and development. This experiment also suggested that the iris embryo of itself does not exhibit true dormancy but is capable of prompt germination when removed from the influence of the inhibiting substances. However, this experiment was performed with dry seed that had been stored at room temperature for several months. Thus there remained the possibility that the embryos of freshly harvested seed might exhibit true dormancy and not begin to grow when removed from the seed.

In the following year the experiment was repeated with freshly harvested seed. Mature unopened capsules of four different varieties were harvested from August 10 to August 20, 1942, and placed directly in a refrigerator at 4 degrees C. On August 22 the embryos of 255 seeds, including from 30 to 120 from each of the four varieties, were excised and cultured in sterile nutrient agar as described in the preceding experiment. An additional 20 intact seeds were surface sterilized and transferred to culture bottles containing nutrient agar to serve as a control. Fifty seeds were also thoroughly air-dried and planted directly in the greenhouse to serve as an additional control. Within 10 days most of the excised embryos had germinated and within 26 days many possessed a well developed root system and seedling leaves. Transfer from the culture bottles to soil in 2-inch pots was made from September 17 to November 11 as rapidly as the seedlings attained sufficient shoot and root growth to warrant their transfer. Thereafter, seedling growth progressed rapidly under ordinary greenhouse conditions, and from December 7 to January 10, 1943 the seedlings were transferred to larger 3-inch pots. On May 20, 152 young plants obtained from the original 255 excised embryos were transplanted to an experimental plot in the field and less than 1 month later flowering of some of the seedlings had commenced. Although most of the 255 excised embryos germinated, losses from contamination of the nutrient agar, failure of a certain number of the seedlings to survive transplanting and the discarding of inferior seedlings reduced their number materially in this experiment. As this is being written (June 26, 1943), 18 or 15 per cent of the 152 seedlings are blooming in the field within 10 months after the seed was harvested. None of the intact seeds which were planted on nutrient agar as a check had germinated by November 11 and were discarded. Of the 50 seeds planted in the greenhouse directly in soil, 18 germinated during the period from December 7 to January 10. These were planted in the field on May 20, along with the much larger seedlings obtained from the excised embryos. None of these 18 seedlings show any evidence of flowering, and because of their small size undoubtedly will not flower until next year.

This experiment demonstrated that excised embryos of freshly harvested seed are capable of continuing growth without the intervention of a rest period and under favorable cultural conditions may be induced to flower within less than a year from the time the mature seed is harvested. Since from 2 to 3 years is ordinarily required for iris seedlings grown from seed in the usual manner to reach the flowering state, this technic should be of great value to commercial growers and hybridizers of iris.

CHIPPING EXPERIMENTS

In a preliminary chipping experiment designed to facilitate the removal of the inhibiting substances from the seed, a portion of the seed coat and underlying endosperm involving an area of several square millimeters was removed indiscriminately from the regions of the seed other than the hilar region. Seeds chipped in this manner and then soaked overnight in water germinated no better than did unchipped seeds. In another experiment comparable to that of Crocker (3) the seed coat and endosperm tissue in the hilar region of seeds, that previously had been soaked in water for 24 hours, were removed to expose the tip of the radicle of the embryo. The chipped seed, and a similar lot of unchipped seed to serve as a control, were placed on moist filter paper in petri dishes and held at room temperature. The seeds used in these experiments had been dried and stored at room temperature for 3 months preceding the start of the experiment. Within 3 days the embryos of 16 seeds in the group of 60 that were chipped to expose the radicle had elongated sufficiently to project 1 to 3 millimeters from the seed. Within 4 weeks 12 of these 16 embryos had produced well-developed seedlings and an additional 5 embryos had commenced to germinate. During the same period none of the 60 unchipped seeds showed any evidence of germination. This experiment was repeated with 100 seeds that were similarly chipped to expose the radicle of the embryo. The results were similar to those obtained previously. Within 48 hours elongation of the embryos had commenced and 24 hours later further elongation accompanied by geotropic bending was noted in approximately 10 per cent of the seeds. Later, additional seeds continued to germinate and at the end of the 4-weeks' period, 34 per cent of the seeds had germinated (elongation of the embryo accompanied by geotropic bending of the radicle was taken as the criterion of germination) and an additional 6 per cent had elongated sufficiently to project 1 to 3 millimeters from the seed, but had ceased growth at that stage.

These chipping experiments, which involved the removal of the cap of endosperm tissue covering the radicle of the embryo, effectively initiated growth within a short period of time in approximately 35 per cent of the seeds treated in this manner, presumably by facilitating the entrance of water, the exchange of gases, and outward diffusion which in turn may have removed or inactivated a sufficient amount of the inhibiting substance surrounding the embryos to permit germination to proceed. None of the unchipped seeds germinated during the same period. These results with garden varieties of bearded iris are not in agreement with those of Crocker (3), who obtained 97 per cent germination in *Iris sibirica* and *I. pseudacorus* within 20 days by chipping the seeds.

Storage of the moist chipped seeds at a temperature of 4 degrees C for 3 weeks did not have a beneficial effect on germination, although cold storage of unchipped seeds was beneficial, as previously described. The total number of seeds which germinated following such treatment of 100 seeds was essentially the same as that of chipped seeds germinated at room temperature. It is possible that chipping and cold storage act in a similar manner, which was not accentuated when both treatments were applied simultaneously.

LEACHING AND CHIPPING EXPERIMENTS

A further increase in the percentage of seeds that could be induced to germinate promptly was obtained by combining the chipping technic with leaching in running water. The chipped seeds were placed in petri dishes under faucets adjusted to drip water constantly into the dishes, thus supplying the seeds with a continuous supply of freshly aerated water. As soon as the seeds began to germinate, they were transferred to moist filter paper for a few days and thence to soil under conditions favorable to normal seedling growth. A preliminary trial with 50 chipped seeds leached for 3 weeks, the germinating seeds being transferred to soil in the greenhouse as rapidly as they appeared, resulted in the production of 37 healthy seedlings fully established in the soil within 5 weeks after the experiment was started. Upon repeating the experiment with 100 chipped seeds and 50 unchipped seeds leached in running water for 3 weeks, 56 seedlings were obtained from the chipped seeds and none from the unchipped seeds. Combining the data from the two experiments 62 per cent of the treated seeds germinated, while none of the unchipped seeds germinated during this same period. The 50 unchipped seeds were later planted in soil and produced 14 seedlings during the following two months, thus approximating the germination obtained from untreated seeds planted directly in the greenhouse.

INCREASED OXYGEN PRESSURE

The effect of increased oxygen pressure on the dormancy of iris seed was determined in the following manner. Dry seeds that had been stored at room temperature for 2 months were soaked overnight in tap water, surface sterilized for one hour in a 2 per cent aqueous solution of calcium hypochlorite and placed between moist paper toweling in half-liter, sealed jars. In one of two jars prepared in this manner, each of which contained 100 seeds, the concentration of oxygen was increased to approximately 50 per cent of the volume of the atmosphere by displacing 20 cubic centimeters of the air in the jar with pure oxygen. The other jar containing the normal content of 20 per cent atmospheric oxygen served as a control. After 1 month both lots of seed were planted in soil in the greenhouse. Four months later 23 of the 100 seeds that had been stored in an atmosphere containing the normal amount of oxygen had germinated, and 16 of the 100 seeds stored in an atmosphere containing 50 per cent oxygen had germinated. This experiment, performed in 1940–41, indicated that increased oxygen concentration at room temperature for 1 month had no stimulating effect on germination of moist iris seed.

In November 1942, the experiment was repeated with chipped and unchipped seed stored at 4 degrees C in the presence of additional oxygen and without additional oxygen. The seed was prepared as in the preceding experiment, 100 seeds being placed in each of four sealed jars. Unchipped seeds were placed in two of the jars, one of which contained the normal concentration of 20 per cent atmospheric oxygen and served as a control; in the other jar the concentration of oxygen was increased to 50 per cent. The seeds placed in the remaining two jars were chipped to remove the seed coats and endosperm tissue covering the radicle of the embryo; in one of these jars the concentration of oxygen was increased to 50 per cent, the other contained the normal concentration of 20 per cent oxygen. All four jars were stored at 4 degrees C for 1 month. The seeds were then placed in petri dishes on moist filter paper and held at a temperature of 18 to 25 degrees C to observe the effect of the treatments on germination. As in preceding experiments which involved chipping the seed, elongation of the embryo accompanied by geotropic bending was taken as the criterion of germination. The embryos of chipped seed may elongate sufficiently to project 1 to 3 millimeters from the seed without further growth, but continuing growth accompanied by geotropic bending ordinarily resulted in normal seedling development.

The percentage germination following a transfer of the seeds from storage at 4 degrees C to room temperature was recorded at weekly intervals as follows:

	First Week	Second Week	Third Week	Fourth Week	Fifth Week
Intact seeds, no additional oxygen	0	0	3	5	5
Intact seeds, increased oxygen pressure	0	1	3	6	7
Chipped seeds, no additional oxygen	11	14	18	22	22
Chipped seeds, increased oxygen pressure	10	26	34	36	36

Increased oxygen pressure had no significant effect on the germination of intact seeds stored in a moist atmosphere at 4 degrees C for 1 month. However, chipped seeds in an atmosphere containing no additional oxygen germinated appreciably better than did the unchipped seeds in a similar atmosphere, and increasing the oxygen pressure of the chipped seeds resulted in an additional significant increase in germination of the seeds during the 4-week period following treatment. Apparently, the intact seed restricted the entry of sufficient amounts of both water and oxygen to induce germination of any appreciable number of seeds during the 9-week period the experiment was in progress. When atmospheric oxygen and water were made readily available to the embryos by chipping the seeds to expose the tip of the radicle the percentage germination was increased, and there was a further increase when additional oxygen was made available.

COMBINED CHIPPING, INCREASED OXYGEN PRESSURE AND LEACHING TREATMENTS

If the improved germination obtained by chipping the seeds to expose the radicle and by exposure to additional oxygen pressure was due to the removal by outward diffusion or inactivation of the inhibiting substances surrounding the embryo it seemed plausible to assume that a still higher percentage of germination might be obtained by leaching the seeds which previously had been chipped and subjected to increased oxygen pressure. Accordingly, the preceding experiment was repeated, except that the seeds were leached in running water for 3 weeks rather than being germinated on moist filter paper. Leaching increased very materially the germination of the chipped seeds supplied with no additional oxygen. Sixty four per cent of the leached seeds germinated as contrasted with the 22 per cent germination obtained by placing the seeds on moist filter paper. However, the seeds that were leached after being chipped and supplied with additional oxygen while being stored at 4 degrees C subsequently germinated only slightly better than the unleached seeds treated similarly, the actual percentages being 36 for the unchipped seeds and 42 for the leached seeds. A sample of 50 seeds of the same lot that gave 64 per cent germination when leached for 3 weeks in running water after being chipped and stored in a moist atmosphere for 4 weeks, was planted as a control directly in soil in the greenhouse. Four months later only 23 per cent of these seeds had germinated.

Leaching and increased oxygen pressure were about equally effective in stimulating prompt germination of chipped seeds stored at 4 degrees C on moist filter paper; but the combination of the two treatments was not much more effective than either applied separately. The failure of such drastic treatments as the exposure of the cavity within the seed which contains the embryo by chipping away the protective layers of the seed in the region of the hilum, and the additional application of increased oxygen pressure followed by prolonged leaching in flowing water indicates that the substances that inhibit germination are highly stable compounds, relatively insoluble in water and not readily diffusible away from the tissues surrounding the embryo. The only effective method of obtaining prompt and essentially complete germination of iris seed thus far devised is to entirely remove the endosperm tissue which contains the inhibiting substances and culture the embryos separately on a sterile nutrient-agar medium.

NEGATIVE RESULTS OBTAINED FROM PLANTING FRESHLY HARVESTED SEED AND FROM PROLONGED STORAGE OF AIR-DRIED SEED

Lots of 250 mature seed collected from ripe unopened capsules were planted at once in moist garden soil for comparison with a similar lot of seed that had been thoroughly air-dried for 3 weeks. In 1938, and again in 1940 when the test was repeated, the air-dried seed germinated better than did the moist, freshly harvested seed, the actual percentages being 26 versus 18 for 1938, and 38 versus 16 for 1940. Prolonged storage of air-dried seed at room temperature for various periods of time up to two years, however, had no appreciable effect on either dormancy or viability, according to data obtained from 1937 to 1941.

These tests indicate that air-drying the moist, freshly harvested seed before it was planted had a beneficial effect on germination, and that continued storage for several years in the air-dry condition had no pronounced effect on either germination or viability.

LONGEVITY OF IRIS SEED

The viability of iris seed that had been stored at room temperature in ordinary seed packets for periods of 2, 4, and 12 years was determined in the following manner. Samples comprising mixed lots of open-pollinated seeds, each lot having been collected from many different varieties of bearded iris, were soaked in tap water for 24 hours, surface sterilized for 2 hours with a saturated aqueous solution of calcium hypochlorite, and chipped to remove the cap of tissue covering the radicle of the embryo. The seeds were then placed in petri dishes containing tap water that was constantly replenished from faucets adjusted to drip water into the dishes. As soon as embryos of individual seeds elongated sufficiently to project approximately 1 millimeter beyond the surface of the endosperm they were transferred to moist filter paper in petri dishes maintained at room temperatures. Daily records of germination were kept. In doing this it was necessary to record separately the number of embryos that had elongated and the number that showed in addition to elongation, evidence of geotropic bending and development into normal seedlings, since some embryos elongated but failed to continue growth. The first trials were made with lots of approximately 50 seeds and the results at the end of 15 days are recorded as Series A in Table IV. The experiments were then repeated with additional samples of seed, one series being chipped and leached as in the preceding trial, and a second series being chipped and then stored at 4 degrees C in an atmosphere of 50 per cent oxygen for 3 weeks and finally leached in flowing tap water for 15 days. The results of these trials are recorded as Series B and C in Table IV.

These data demonstrate conclusively that iris embryos remain viable in air-dried seed stored at room temperature for as long as 12 years. Furthermore, there was no significant difference in the percentage of the seed that was germinable after 2, 4, and 12 years. In fact the agreement is remarkably good for samples collected in different years. The

TABLE IV—GERMINABILITY OF IRIS SEED AFTER 2, 4, AND 12 YEARS

Age of Seed in Years	Experiment Series	No. Elongated Embryos	No. of Embryos Which Continued Development	Total No. Seeds	Per Cent Germination
2	A	32	28	42	45.8
	B	47	38	74	51.3
	C	29	22	66	33.3
4	A	34	28	53	52.8
	B	37	31	60	51.7
	C	38	32	63	50.8
12	A	35	26	50	52.0
	B	43	31	74	41.9
	C	34	26	60	43.3

percentage germination of this old seed also compared favorably with that of seeds germinated in a similar manner within a few weeks or months after they were harvested. However, the seeds that were 12 years old germinated somewhat more slowly than did the seeds that were only 2 and 4 years old.

The ability of old seed to germinate without pretreatment of any kind was demonstrated by planting a small sample of 25 seeds that were 12 years old directly in soil in the greenhouse. Within 3 months this old seed had produced six seedlings that were normal in appearance and comparable in size to seedlings obtained from seed harvested the previous year and planted at approximately the same time. These results with old seed tend to confirm the statement attributed to Sir Michael Foster (4) that iris seed is apparently capable of remaining viable for from 15 to 18 years. They also lend additional support to the conclusion drawn from the numerous experiments reported here that the substances which inhibit germination are highly stable compounds that are not readily influenced by the environmental conditions that normally surround the seed.

SUMMARY AND CONCLUSIONS

Iris seed normally remains dormant for several months followed by partial, intermittent germination over a period of several years. The percentage germination obtained from different samples of seed varies markedly. During the 4-year period from 1938 to 1941, from 14 to 50 per cent of the seeds planted in the fall shortly after being harvested and thoroughly air-dried, germinated the following spring. An average of 35 per cent germination was obtained from a total of 12,459 seeds, including 125 cultures; individual cultures gave from 0 to 72 per cent germination. An additional 10 to 15 per cent of these seeds germinated the second year after being planted.

The delayed and incomplete germination of the seed is a serious obstacle to progress in iris breeding. In an effort to improve the germination of the seed, numerous experiments of an exploratory character were made. From these, the most successful results were obtained by removing the embryos from the seed and culturing them on sterile nutrient agar. Embryos of freshly-harvested as well as air-dried seed that had been stored at room temperature for several months germinated within a few days after being transferred under aseptic conditions from the seed to the sterile nutrient agar, and within a few weeks seedlings with well developed roots and shoots suitable for transplanting to soil were obtained from approximately 90 per cent of the embryos that were cultured in this manner. The remaining 10 per cent either aborted or produced malformed, defective seedlings which were subsequently discarded; rarely did normal appearing embryos fail to germinate. The number of such atypical embryos varied in the different samples of seed, and germless seeds were also present in certain samples.

Seedlings produced with this excised embryo technic from crosses made in 1942 flowered in 1943, thus reducing to less than one year the interval from seed to flowering, which normally requires from 2 to 3 years.

Of even greater significance to the hybridizer interested in the cytology and genetics of iris is the fact that there is now available a reliable method of obtaining seedlings from crosses that are difficult to make and from which relatively few seeds may be obtained, as well as from crosses producing abundant seed that may or may not germinate satisfactorily under natural conditions.

Inhibiting substances present in the mature seed prevent further growth of the embryo and thus function to maintain the seed in the dormant condition. Embryos of ripe seed when completely detached from the endosperm with which they were normally in contact germinated promptly, but when left in contact with even a portion of the endosperm their growth was inhibited or progressed slowly in an atypical manner.

Experiments designed to obtain prompt germination of the seed by removal or inactivation of the inhibiting substances without the necessity of resorting to the excised embryo technic were only partly successful. Storage for a period of several weeks at near-freezing temperatures, chipping the seed in the region of the hilum to remove the cap of tissue covering the radicle of the embryo, increased oxygen pressure applied to chipped seeds, and leaching, increased germination in some instances from the usual 15 to 20 per cent obtained from untreated seeds to as high as 64 per cent for certain treatments. Alternating low and moderate temperatures was no more effective in stimulating germination than was a continuous low temperature treatment of several weeks, nor did the use of media varying in hydrogen ion concentration within a range of pH 4.1 to 8.5 have any appreciable effect on germination.

Failure to obtain higher percentages of germination by such treatments suggested that the inhibiting substances were highly stable compounds, relatively insoluble in water and not readily diffusible from the region of the embryo. The present investigation was not concerned with the identification of the chemical nature of these inhibiting substances.

In relation to common practices in germinating iris seed it was found that thoroughly air-dried seed germinated better than freshly harvested seed when planted under field conditions in specially prepared seed beds. Also light was found not to be an important factor either during the drying or after-ripening of the seed.

A study of the longevity of iris seed indicated that air-dried seed stored in ordinary seed packets remained viable for 12 years, and storage for at least several years had no appreciable effect on the germination of the seed.

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Adventitious Root Initiation in Forsythia Suspensa

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MANY anatomical studies of the development of adventitious roots from stem-cuttings have been reported. In most plants, adventitious roots originate at or near the base of the cutting, regardless of where the basal cut is made; in other plants, adventitious roots are characteristically related to the node or internode. Chadwick (2) observed a number of plants that regularly exhibited peculiar rooting habits. One of these, *Forsythia suspensa,* developed roots from buds when stem-cuttings were placed in a rooting medium. This suggested an anatomical investigation of the origin and development of adventitious roots in *F. suspensa.* A review of the literature has revealed no mention, except for Chadwick, of the development of roots from normal buds. While working with *F. suspensa,* the writer observed the development of roots from the petioles and veins of young leaves. According to an extensive study made by Hagemann (3) on this subject, the place of origin of roots on leaves in all cases investigated was parenchymatous tissue closely associated with the vascular cambium of the main bundle. To find if this were true in Forsythia, anatomical studies were made.

Methods and Materials

Softwood cuttings that were sufficiently mature to remain turgid on the propagating bench were collected April 15. The basal cut was made 5 to 8 millimeters below the node. Some cuttings were treated with indolebutyric acid and naphthylacetamide in talc mixtures of 1 to 500 to observe the effect of synthetic growth substances on the characteristic root development. All cuttings were placed in sand in a propagating house. To follow the development of root primordia, pieces of the stem-cuttings about 8 millimeters long were cut at 4-day intervals and fixed in formalin-acetic acid-alcohol. Shortly after immersion in the fixative, these pieces were placed under a bell jar and the air slowly pumped out until a displacement of air equaled 600 millimeters of mercury. Then the air was allowed to slowly return. Each part of the process required from 15 to 30 minutes.

The material was dehydrated by means of the tertiary butyl alcohol method. After complete dehydration, the usual procedure was amended by changing to a 50 per cent mixture of tertiary butyl alcohol and toluene, then to pure toluene. The material was infiltrated with rubberized paraffin, melting at 56 to 58 degrees C by gradually increasing the concentration of paraffin in a toluene mixture. By using this method, the larger stem pieces may be infiltrated more successfully. Transverse and longitudinal sections, 8 to 12 microns thick, were cut serially and stained with iron haematoxylin and Bismark brown, according to a schedule outlined by Blaydes (1). Cutting was facilitated if the paraffin blocks were soaked overnight in a 2 per cent solution of formalin.

Adventitious Roots in Forsythia Suspensa

A maximum of eight adventitious roots may appear at each node. Two roots emerge from each of the two opposite buds, usually at a level about one-third the distance from the base to the apex. They appear on either side of the median line and diverge so that each is almost in line with the other. Sometimes these roots emerge from the upper half of the bud. Two roots also emerge at nearly the same level on either side of each bud. Fig. 1 illustrates typical root development at the node. Occasionally, one or more roots may emerge directly below the roots appearing at the side of the bud. There is no apparent order in the emergence of roots. Sometimes those from the buds emerge first, at other times those beside the buds appear first. Usually, only four

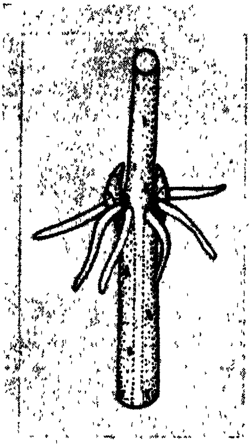


Fig. 1

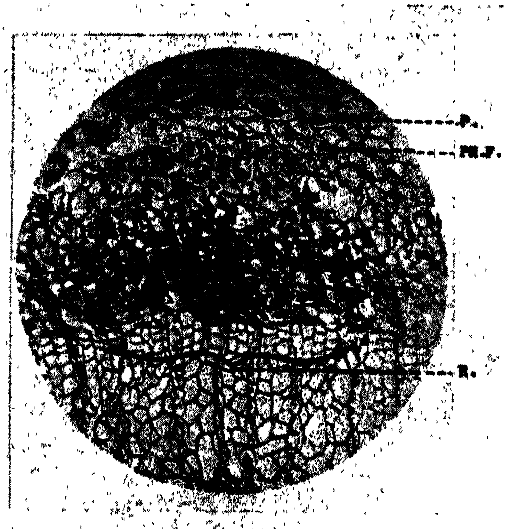


Fig. 2

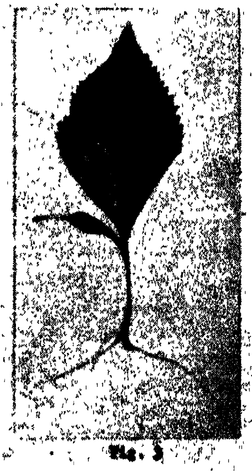


Fig. 3

Fig. 1. Diagram of a cutting to show the emergence of roots from the buds and from that part of the stem between the buds.

Fig. 2. A primordium (R) in which the form of a root is just evident; phloem cells have become meristematic and cells in the central portion have begun to elongate, indicating the beginning of a vascular system. (P) pericycle in which the activity of a cork cambium is evident; (PH.F.) phloem fibers. Magnified 160 ×.

Fig. 3. Photograph of a leaf cutting with roots on the petiole.

or five roots develop at each node, infrequently the maximum number of eight roots develops. Nodal roots began to appear on some cuttings about 25 days after placement in the propagating medium. On most of these cuttings, basal roots, developing in the region of the vascular cambium and breaking through the callus tissue, began to appear about 10 days later.

Root development in treated cuttings was not materially different from that in untreated ones. The development of roots in the nodal region was exactly the same as just described. The average number of nodal roots was approximately the same, regardless of treatment. However, several to many roots appeared between the basal callus and the node on at least 50 per cent of the treated cuttings. This increase was more pronounced on cuttings that had been treated with indolebutyric acid. As previously mentioned, only one or two roots occasionally appeared in this region on untreated cuttings and these were always directly below the roots that emerge beside the bud.

When layered stems under plants of *Forsythia suspensa* were examined, only nodal rooting was found. Further observation disclosed that roots had grown from some leaves that were still attached to stems but partially covered with litter. Roots had developed from various parts of the petiole, from the midrib and occasionally from a lateral vein. On such leaves and on immature leaves taken from branches lying on the ground and handled as cuttings, roots emerge from the lower or rounded surface of the petiole near the two edges. They develop in nearly the same plane as the blade. More mature leaves taken from upper branches behave quite differently when handled as cuttings. Roots emerge from the upper or grooved surface of the petiole, also in two rows but farther from the edges and they develop at about a 60° angle instead of in the same plane. Fig. 3 is a photograph of a leaf cutting with roots. Partially etiolated leaves from immature, succulent stems rooted readily in less than a month. Shoots failed to develop from all leaves observed.

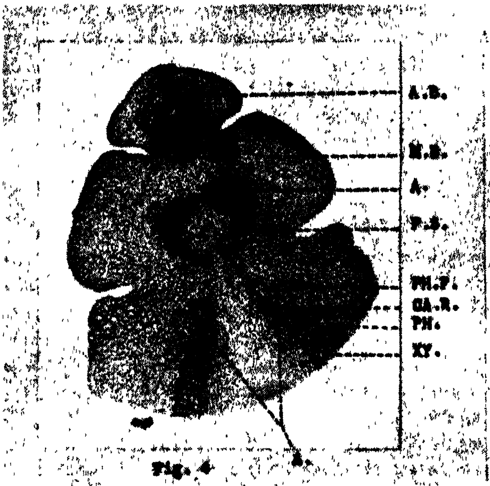
Vascular Arrangement at Node:—Upon investigation of the internal structure of the stem, below the node, it was discovered that a single leaf trace is evident in the vascular cylinder, a considerable distance below the insertion of the leaf, but within the same internode. Just below the insertion of the leaf, two very small accessory traces extend from the outer lateral portions of the main trace. These diverge rapidly, then extend obliquely through the cortex and into the petiole, where they are widely separated from the main bundle. Near the base of the petiole, another small bundle extends from each accessory bundle. In the upper part of the petiole, a bundle extends from the main bundle into the first leaflet or the first lateral vein, as the case may be. The small accessory bundles in the petiole extend as accessory bundles in the first leaflet or lateral vein; above this point, in the mid-rib, other accessory bundles extend from the main bundle.

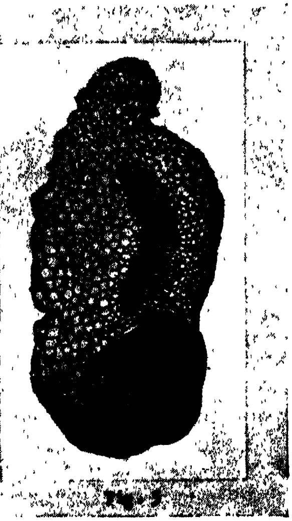
In the stage of growth investigated, the xylem is nearly continuous, separated only by numerous rays of one cell thickness. Many of the rays are continuous through the cambial layer and the phloem. Partly because the stems were very young, the cambial region is difficult to distinguish from adjoining layers of cells that will differentiate into either xylem or phloem. Phloem fibers are present. The activity of a cork cambium is apparent in the region of the pericycle. No endodermis is visible. In a transverse section of the bud, the procambial strands, connected with the main vascular system of the stem, are very distinct. Some vessels have differentiated but most of the cells in these strands are still in a meristematic condition.

Anatomical Study of Root Primordia:—Root primordia were not detected in cuttings that had been in the rooting medium less than 18 days. The root primordia in the buds are formed in procambial strands that compose the promeristem of the embryonic stem tip (Fig. 4). In transverse section, they originate in the outer lateral portions of the procambial strand at about one-third the distance from the base of the bud to the apex. Sometimes, the place of origin is slightly above this level, sometimes it is slightly below. Meristematic cells in the strand, at the place indicated, begin active division in a predominantly tangential direction. Adjacent parenchyma cells also divide and thus contribute to root primordia. Cells in the central portion of the primordium begin to elongate, then more and more differentiation occurs until the root is fully differentiated before it disrupts the remaining layers of parenchyma. The relationship of root primordia to parts of the bud is shown in longitudinal section in Fig. 6.

At about the same time or earlier, root primordia form in the vascular cylinder, usually at the same level as in the buds or somewhat below that level. Occasionally they form below the node. These primordia always form on either side of the branch trace (Fig. 4), although there is some variation in the proximity of the initials to the trace. Since the stems were comparatively young, numerous meristematic cells are present in the cambial region. Therefore, it was virtually impossible to detect root primordia with only a few cells in cross section. Root primordia could not be detected with any degree of certainty until a definite rounding was apparent. Several layers of meristematic cells lie between the xylem vessels and the phloem and no one layer could be distinguished as the cambium. It can be concluded only that the roots originate from cells that are closely associated with the cambium. As the root primordium becomes larger, the phloem parenchyma definitely contributes to its development (Fig. 2). Elongation of cells occurs in the central portion of the primordium at about this stage and further organization takes place while the root is growing through the cortex. The pericycle is pushed out and partially crushed by the growing primordium. This is good evidence that the pericycle does not contribute to the development of the primordium. Organization of the root is complete before emergence.

Root initiation in the layered stems was found to have occurred only in the cambial region of the central cylinder. The place of origin and manner of development was the same as that described for stem-cuttings. The lack of root initiation in the buds may be explained by the insufficient maturity of buds in the young, succulent, layered branches. The buds were flattened rather than rounded. There is some additional evidence for this explanation. In stem-cuttings, it was noted





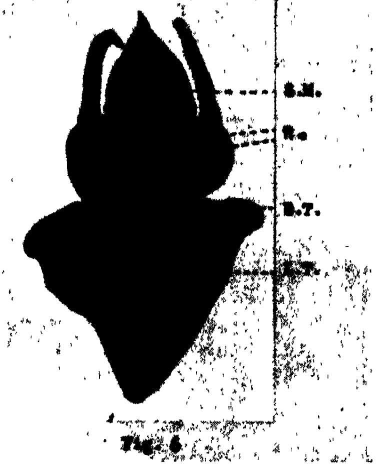


FIG. 4. Cross section of a stem cutting, through the node, near the base of the buds, at about the level that root primordia usually appear. (A.) place of origin of nodal roots; (A.B.) accessory bud; (M.B) main bud; (P.S.) procambial strand; (PH.F.) phloem fibers; (PH.) phloem; (CA.R.) cambial region; (XY.) xylem. Magnified 18 X.

FIG. 5. A young root that developed in the region of an accessory bundle. The root is growing toward the rounded or lower side of the petiole. This is the usual manner of root development in immature leaves. Magnified 35 X.

FIG. 6. Longitudinal section of a stem-cutting through the bud, including a part of the stem. (R.) roots from the procambial strand, cut approximately in transverse section; (S.M.) shoot meristem; (B.T.) bud trace; (L.T.) leaf trace. Magnified 18 X.

that no roots originated in poorly developed buds on immature shoots.

In the immature and somewhat etiolated leaves collected from partially layered branches, most primordia observed, had developed from the small accessory bundles (Fig. 5). The exact origin was not determined. Of seven such primordia studied, six were growing toward the lower or rounded part of the petiole or midrib. A few primordia originated near the lateral part of the main bundle, apparently in phloem parenchyma. In cuttings of more mature but still succulent leaves, on the other hand, most primordia originated from the main bundle and only a few from accessory bundles. Nearly all of these primordia grow toward the upper or grooved part of the petiole. The general statement can then be made that root primordia in immature leaves usually originate from accessory bundles and emerge from the lower or rounded part of the petiole while primordia in mature leaves usually originate from main bundles and emerge from the upper or grooved part of the petiole.

SUMMARY

An anatomical study of adventitious roots in *Forsythia suspensa* was suggested by a report from Chadwick (2) that roots develop from the buds of stem-cuttings of this species, and that other roots are definitely related to the node. Softwood cuttings were collected April 15 and placed in sand in a propagating house. Pieces of the stem-cuttings about 8 millimeters long were cut at 4-day intervals, fixed and run through the paraffin schedule.

A maximum number of eight roots may appear at each node, but the usual number is four or five. Two roots may emerge from each bud, usually near the base. One root may emerge at the side of each bud, that is, four roots between the buds at nearly the same level. Isolated, immature leaves root readily when placed in a favorable propagating medium but do not produce shoots. Roots appear mostly from the petiole, occasionally from the midrib or lateral veins.

Young root primordia were detected in stems that had been in the rooting medium 18 days. The primordia in the bud develop from meristematic cells in the outer lateral portions of the procambial strand. The primordia in the stem develop from cells in the region of the vascular cambium on either side of the branch trace. Phloem parenchyma becomes meristematic and contributes to the developing primordia. In immature, partially etiolated leaves, most primordia form from undetermined cells in the region of the small accessory bundle and develop through the lower or rounded part of the petiole. In more mature leaves, most primordia form from the main bundle and develop through the upper or grooved part of the petiole. Treatment with synthetic growth substances did not noticeably affect the number or origin of nodal roots, but did increase the number of internodal roots. Very few untreated cuttings developed internodal roots.

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Low Temperature and Flower Bud Development of Azaleas

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SKINNER (1) found flower bud formation of azaleas occurred when temperatures were 75 to 80 degrees F and that further development of the flower bud occurred at 35 to 50 degrees F. The commercial florist must know at what time of year the plants should be placed at the low temperature, the length of time the buds must be given the low temperature of storage before they can be forced into flower and the light conditions under which the plants should be kept during the storage period. The following experiments were planned to supply this information.

Plants of the variety Triumph, an Indica type, and Coral Bells, a Kurume type, were obtained through the courtesy of William W. Hannell and Sons, Watervliet, New York. They were obtained in 4-inch pots during May and shifted to 5-inch pots and grown at Cornell. All plants were kept in coldframes until the date of the storage treatment. Plants were not trimmed after May. Flower buds were well developed on both varieties at the time the treatment was started.

The plants were equally divided into lots but due to some plants dying, the result was an unequal number of plants per treatment. At the time of flowering the growing points were counted and each week the number of flowers were counted and removed from the plants. The treatments were so arranged that one lot of plants was placed in the refrigerator August 1, September 1 and October 1 respectively. Half of each lot was lighted in the refrigerator. Plants from each lot were removed to the 60 degrees greenhouse after 4, 6, 8 and 10 weeks respectively. Plants not treated but carried in the coldframes constantly were placed in the greenhouse with each lot removed from the refrigerator.

The experiment was arranged so that the plants lighted in storage and those not lighted could be calculated together to determine the effects of storage time and time of forcing, and so that all lighted plants could be calculated in one unit and unlighted plants in another to determine the effects of light in the storage treatment.

The refrigerator temperature varied from 40 to 41 degrees F during the treatment. The light was supplied from 150-watt Mazda bulbs with reflectors which gave a light intensity of 35 to 100 foot candles at the top of the plants. They were operated with an automatic time switch permitting the light to be on 12 hours of each day.

The data in Table I show that plants of Coral Bells placed at 41 degrees F August 1 and kept there 1 month produced more than 40 per cent of their flowers during the 4th and 5th weeks after they were placed at 60 degrees. Plants not given the storage treatment and put in 60 degrees on September 1 flowered very unevenly and in no 2-week period did they produce more than 33 per cent of the flowers. Eight weeks at 60 degrees was necessary before any appreciable number of flowers were produced. All storage treatments

TABLE I—EFFECTS OF STORAGE PERIOD (CORAL BELLS)

Date Placed at 41 Degrees F	Date Placed at 60 Degrees F	Number Plants	Total Number Growing Points	Average Number Flowers Per Growing Point	Per Cent of Flowers—Weeks of Forcing									
					3	4	5	6	7	8	9	10	11	12
Aug 1	Sep 1	6	662	1.85	11.6	23.4	18.8	7.2	5.4	6.0	9.2	9.6	6.0	2.0
Aug 1	Sep 15	8	1037	1.86	—	35.5	29.5	11.6	8.7	5.6	6.4	2.5	—	—
Aug 1	Oct 1	8	937	1.32	3.1	60.1	9.9	10.8	9.8	6.1	—	—	—	—
Aug 1	Oct 15	6	771	1.51	3.5	53.4	11.1	14.4	8.0	6.9	2.3	—	—	—
Sep 1	Oct 1	5	731	1.30	—	21.2	38.3	18.0	9.3	3.2	7.1	2.9	—	—
Sep 1	Oct 15	5	620	1.69	0.5	25.0	60.0	5.5	1.8	2.3	2.7	1.8	—	—
Sep 1	Nov 1	5	690	1.04	—	—	78.4	10.5	4.1	6.8	—	—	—	—
Sep 1	Nov 15	5	578	1.38	—	33.7	57.7	4.4	4.0	—	—	—	—	—
Oct 1	Nov 1	4	702	1.33	—	—	70.7	19.8	4.9	4.4	—	—	—	—
Oct 1	Nov 15	4	617	1.01	—	44.3	47.7	1.7	6.1	—	—	—	—	—
Oct 1	Dec 1	4	711	1.18	—	46.6	53.4	—	—	—	—	—	—	—
No storage	Sep 1	3	357	1.44	—	—	—	—	—	21.7	6.6	4.6	9.1	6.0*
No storage	Sep 15	1	105	1.34	1.4	1.4	—	32.8	18.6	2.8	0.7	3.6	10.0	28.6
No storage	Oct 1	2	311	1.41	—	7.7	25.7	14.5	6.6	6.1	7.9	11.6	12.5	7.0
No storage	Oct 15	2	264	1.13	9.0	6.3	35.7	2.3	11.0	10.1	13.7	11.7	—	—

*13 weeks, 7.0, 14 weeks, 7.7, 15 weeks, 25.2, and 16 weeks, 12.0.

started at a later date gave similar results excepting plants put in storage later gave a greater percentage of flowers at one time and in a shorter time after they were removed from storage. Probably the normal low temperature affecting the plants in the coldframe added to the storage treatment hastened bud development. Plants not placed in storage but placed at the forcing temperature October 15 produced 50 per cent of their flowers during the 3rd, 4th and 5th weeks of forcing showing that the normal coldframe temperature was sufficiently low to cause flower buds to develop. Plants held in the refrigerator 6, 8 and 10 weeks produced more flowers during the 4th week at 60 degrees but the difference was only slight.

The average number of flowers per growing point during the entire period of flowering varied greatly and appeared to be greatest when

TABLE II—EFFECTS OF STORAGE PERIOD (TRIUMPH)

Date Placed at 41 Degrees F	Date Placed at 60 Degrees F	Number Plants	Total Number Growing Points	Average Number Flowers Per Growing Point	Per Cent of Flowers—Weeks of Forcing									
					4	5	6	7	8	9	10	11	12	13
Aug 1	Sep 1	8	495	0.95	—	1.2	2.4	15.4	31.1	28.9	10.5	6.1	4.2	—
Aug 1	Sep 15	8	464	0.65	—	2.7	7.2	10.4	21.7	22.5	24.2	5.8	1.6	3.4
Aug 1	Oct 1	8	460	0.56	—	3.2	15.5	22.4	15.3	23.2	13.5	4.3	2.2	—
Aug 1	Oct 15	8	439	0.43	—	3.5	53.4	11.1	14.4	8.0	6.9	2.3	—	—
Sep 1	Oct 1	8	436	0.50	—	—	15.2	29.5	14.9	22.7	12.8	4.4	—	—
Sep 1	Oct 15	7	353	0.42	—	—	31.9	28.7	19.3	12.6	7.2	—	—	—
Sep 1	Nov 1	8	432	0.40	—	—	15.9	37.0	30.6	16.8	—	—	—	—
Sep 1	Nov 15	8	408	0.60	—	—	38.0	21.8	22.3	17.7	—	—	—	—
Oct 1	Nov 1	8	513	0.43	—	—	15.4	43.4	28.6	12.5	—	—	—	—
Oct 1	Nov 15	8	523	0.72	—	—	26.2	28.3	15.7	30.2	—	—	—	—
Oct 1	Dec 1	8	519	0.95	—	—	17.4	54.6	28.0	—	—	—	—	—
No storage.	Sep 1	4	213	0.54	—	—	—	—	3.4	16.3	34.4	11.2	21.5	12.4
No storage.	Sep 15	4	227	0.72	—	—	6.0	21.3	43.9	13.4	10.3	4.8	—	—
No storage.	Oct 1	4	251	0.51	—	15.5	19.3	31.0	13.9	9.3	10.0	—	—	—
No storage.	Oct. 15	4	288	0.53	3.9	7.8	21.7	30.2	17.1	10.5	8.5	—	—	—
No storage.	Nov 1	4	296	0.76	9.0	10.5	18.3	21.5	20.5	12.9	12.3	—	—	—

the plants flowered over a long period of time. Plant differences also account for much of the variation.

The variety Triumph (Table II) reacted in a similar manner to Coral Bells excepting that 6 to 7 weeks of forcing were necessary to obtain an appreciable number of flowers in comparison to the 4 weeks required for Coral Bells. Six or more weeks of storage gave more flowers earlier in the period of bloom than the 4 weeks treatment. The storage treatment was even more effective in producing uniformity of bloom than with Coral Bells. It delayed the buds which were well developed and hastened the development of those which were not as well-developed when the plants were placed in storage.

Light in storage (Table III) had no significant effect on the number of flowers per growing point or the percentage of flowers opening at one time. It likewise had no effect on leaf drop in storage or the size and color of flowers which opened. Leaf drop of all plants occurred after January whether stored or not.

TABLE III—EFFECTS OF LIGHT IN STORAGE

Treatment	Number Plants	Total Number Growing Points	Average Number Flowers Per Grow-Point	Per Cent of Flowers—Weeks of Forcing										
				3	4	5	6	7	8	9	10	11	12	13
				Coral Bells										
Light	30	4035	1.38	2.8	33.7	39.0	9.9	5.2	4.4	3.0	1.3	0.8	—	—
No light	30	4021	1.46	0.8	30.4	44.8	8.4	5.0	3.7	2.1	2.0	0.7	0.7	0.6
				Triumph										
Light	34	2518	0.60	—	—	1.3	14.9	26.9	24.5	22.7	7.2	1.7	0.8	—
No light	35	2724	0.62	—	—	0.3	19.0	29.7	22.6	16.1	7.5	2.6	1.2	0.6

Coral Bells held in storage 8 weeks or more produced smaller flowers with lighter color than plants given a shorter storage period. Previous experiments in storage temperatures of 50 degrees gave much leaf drop. Likewise experiments conducted in refrigerators used for fruit storage were unsuccessful probably because of ethylene gas produced by the fruit.

CONCLUSIONS

1. The storage treatment of 40 to 41 degrees F of Coral Bells and Triumph Azaleas, after buds were well formed, caused uniform bud development and flowering after 4 and 6 weeks of storage respectively.
2. Flowering to a salable stage occurred in 4 and 6 to 7 weeks for Coral Bells and Triumph respectively after storage and placing the plants at 60 degrees F.
3. More uniform flowering of both types occurred when the storage treatment was given than when given normal coldframe treatment.
4. Artificial lights during the storage treatment had no effect on the plants.
5. Excellent salable plants of Coral Bells were obtained October 1 and later and of Triumph November 15 and later.
6. Eight weeks of storage treatment produced smaller and lighter colored flowers of Coral Bells.

7. Care should be taken not to store plants in refrigerators where fruit or vegetables have been kept without a thorough airing previous to placing the azaleas in them.

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The Effect of an Interval of Long Days in the Short Day Treatment on the Flowering of Chrysanthemums

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THE common practice in reducing the length of day to cause early flowering in chrysanthemums consists of covering the plants with black cloth or some other nearly opaque material each afternoon at 5 or 6 o'clock and removing it the following morning at 7 o'clock. This treatment is started during the long day period before the normal date of bud formation, August 25. The plants are treated each day until color shows in the flower or until the days are naturally short enough to permit bud formation. A previous experiment (1) showed that the time of flowering was dependent on the number of short days in proportion to long days in a period of treatment. Flower buds developed less rapidly when long days were interspaced in the short day treatment than when short days continued in succession. Flowering induced by such treatment was earlier than when plants were not treated and it was related to the number of short days in the treatment.

Little or no delay in time of bloom resulted when every seventh day was long as compared with a treatment of all short days. This has resulted in many commercial growers not covering their plants one night each week. It was also found in these early experiments that the amount of budding from the top to the base of the stem was dependent on the number of short days given before the plants were exposed to continuous long days. On a certain variety 2 short days might cause the topmost flower bud, "crown bud", to form whereas 7 short days might cause three or four buds to form from the top down the stem. Different varieties required a greater or smaller number of short days to form buds completely down the stem.

The "crown bud" is formed when a few short days are followed by long days. The terminal bud forms when short days are given continuously. The crown bud develops over a long period of time with long days and normally flowers a few days earlier than the terminal buds which form later and develop with short days. The crown bud usually produces a larger flower head with fewer disc flowers and a longer peduncle than the terminal bud.

The following experiments were designed to determine the effect of a period of long days in the short day treatment which was started on July 3. After several short days, there were a number of long days following which the short day treatment was resumed. The pompon varieties Mrs. Bulkley, Yellow Fellow, Princeton and Chicago Pearl were used in the experiment. Fifteen rooted cuttings of each variety were planted May 25 in each treatment in a cloth house.

The treatments, time of bloom, green weight of stems cleaned for bunching for market, number of stems per plant, number of buds per stem, diameter of the terminal flower and the length of the top four peduncles on the stems are recorded in Table I. All varieties did not react the same under the various treatments, probably because of varietal difference in length of short day treatment required to develop the buds to various stages of growth.

Observations of the varieties revealed that Yellow Fellow and Mrs. Bulkley were budded down the stem after 7 short days while Princeton and Chicago Pearl had formed only two to five buds. After 14 short days, all varieties were budded so that no vegetative growths occurred along the stem when again given 20 long days. The top buds of Prince-

TABLE I—EFFECTS OF A LONG DAY INTERVAL AFTER A VARYING NUMBER OF SHORT DAYS

Plot	Treatment Followed by Short Days	Ave Date Cut	Ave Green* Weight Per Plant (Gms)	Ave stems Per Plant (No)	Ave Weight Per Stem (Gms)	Ave Buds Per Stem (No)	Diam Terminal (Cms)	Ave Peduncle Length (Cms)			
								1	2	3	4
	Variety Princeton										
1A	7 S.D. +5 L.D.†	Sep 21	126.7	5.66	23.4	5.1	6.6	10.3	12.2	13.8	14.6
1B	7 S.D. +10 L.D.	Sep 26	110.7	4.13	26.3	4.9	6.9	11.6	14.6	17.5	19.4
1C	7 S.D. +15 L.D.	Sep 28	96.8	4.40	22.0	4.7	6.6	11.5	15.2	18.0	19.6
1D	7 S.D. +20 L.D.	Oct 17	118.8	3.40	34.9	5.8	6.5	12.4	17.6	23.3	23.8
2A	14 S.D. + 5 L.D.	Sep 24	111.6	4.73	23.6	5.0	6.3	8.2	9.6	11.0	12.0
2B	14 S.D. +10 L.D.	Sep 26	94.6	3.53	26.8	5.2	6.5	9.3	10.9	12.5	13.2
2C	14 S.D. +15 L.D.	Sep 28	114.9	4.20	27.4	4.8	6.2	12.3	13.7	15.2	16.5
2D	14 S.D. +20 L.D.	Oct 16	119.8	3.46	34.6	5.1	7.0	12.1	13.5	15.2	16.5
3A	21 S.D. + 5 L.D.	Sep 22	119.2	5.40	22.1	5.1	5.2	6.9	7.2	8.7	9.6
3B	21 S.D. +10 L.D.	Sep 28	128.1	5.13	25.0	5.2	6.0	8.8	9.8	10.5	11.7
3C	21 S.D. +15 L.D.	Oct 7	87.3	3.26	26.7	5.5	6.2	9.4	10.5	11.6	12.1
3D	21 S.D. +20 L.D.	Oct 7	99.3	3.73	26.6	5.2	6.3	9.3	10.5	11.5	12.1
4A	28 S.D. + 5 L.D.	Sep 19	129.3	5.40	23.9	5.2	6.8	8.8	9.3	10.1	10.7
4B	28 S.D. +10 L.D.	Sep 19	111.9	4.13	25.4	5.3	6.9	10.0	11.2	12.5	13.1
4C	28 S.D. +15 L.D.	Sep 21	108.5	4.60	23.6	4.1	7.0	9.3	9.8	10.7	11.1
4D	28 S.D. +20 L.D.	Sep 23	125.7	5.40	23.3	4.4	7.0	11.1	11.3	12.2	12.6
5A	35 S.D. + 5 L.D.	Sep 19	92.5	4.00	23.1	5.0	6.7	9.8	10.8	12.0	12.6
5B	35 S.D. +10 L.D.	Sep 20	136.3	4.86	28.0	5.7	6.7	11.0	12.2	13.9	14.6
5C	35 S.D. +15 L.D.	Sep 22	136.9	5.33	25.6	5.0	6.9	10.4	11.3	12.2	12.7
5D	— —	—	—	—	—	—	—	—	—	—	—
6	Check (continuous S.D.)	Sep 16	98.3	4.1	24.2	5.3	6.6	7.3	7.3	8.3	8.8
	Variety Yellow Fellow										
1A	7 S.D. + 5 L.D.	Sep 14	132.4	4.46	29.6	7.2	5.14	8.6	9.8	11.5	12.8
1B	7 S.D. +10 L.D.	Sep 15	131.7	4.80	27.4	6.3	4.94	8.6	9.8	11.5	12.8
1C	7 S.D. +15 L.D.	Sep 19	133.1	4.80	27.7	5.8	5.55	10.4	11.8	13.9	15.7
1D	7 S.D. +20 L.D.	Sep 26	102.7	4.33	23.7	6.5	5.32	11.4	13.1	16.1	17.1
2A	14 S.D. + 5 L.D.	Sep 12	123.4	4.40	28.1	6.6	4.75	7.1	8.1	10.0	10.9
2B	14 S.D. +10 L.D.	Sep 15	119.9	5.40	22.2	5.6	5.00	9.1	10.4	11.8	13.0
2C	14 S.D. +15 L.D.	Sep 22	111.4	4.47	24.9	5.9	5.10	10.1	10.6	11.8	12.8
2D	14 S.D. +20 L.D.	Sep 26	—	—	—	—	—	—	—	—	—
3A	21 S.D. + 5 L.D.	Sep 12	130.0	5.86	22.2	6.6	4.54	7.4	7.8	9.7	10.5
3B	21 S.D. +10 L.D.	Sep 16	126.4	4.80	26.3	6.3	4.65	9.4	9.8	11.1	11.7
3C	21 S.D. +15 L.D.	Sep 19	84.1	3.73	22.5	5.4	5.00	9.3	9.9	10.2	10.8
3D	21 S.D. +20 L.D.	Sep 19	95.5	3.66	26.1	5.8	5.18	9.0	10.0	11.3	11.5
4A	28 S.D. + 5 L.D.	Sep 15	143.7	5.26	27.3	7.3	4.7	8.6	9.5	11.1	12.2
4B	28 S.D. +10 L.D.	Sep 15	165.6	5.00	33.1	8.0	4.9	7.3	8.2	10.0	9.9
4C	28 S.D. +15 L.D.	Sep 9	151.3	4.86	31.1	8.1	4.9	7.3	7.6	9.0	10.5
4D	28 S.D. +20 L.D.	Sep 18	154.1	4.93	31.2	7.6	5.0	7.6	7.8	9.4	10.3
5A	35 S.D. + 5 L.D.	Sep 11	155.9	4.33	36.0	9.0	5.0	7.0	8.0	9.1	9.5
5B	35 S.D. +10 L.D.	Sep 10	181.4	4.40	41.2	10.2	5.0	8.0	8.6	10.4	11.0
5C	35 S.D. +15 L.D.	Sep 10	178.1	5.33	33.4	8.7	4.8	8.2	8.9	10.2	11.2
5D	35 S.D. +20 L.D.	Sep 9	146.3	4.06	36.0	9.0	4.8	8.1	8.6	10.3	11.2
6	Check (continuous S.D.)	Sep 10	156.5	3.8	41.2	10.4	4.5	6.8	6.8	8.4	9.2

TABLE I—*(concluded)*

Plot	Treatment Followed by Short Days	Ave Date Cut	Ave. Green* Weight Per Plant (Gms)	Ave stems Per Plant (No)	Ave Weight Per Stem (Gms)	Ave Buds Per Stem (No)	Diam Terminal (Cms)	Ave Peduncle Length (Cms)			
								1	2	3	4
	Variety Mrs. Bulkley										
1A	7 S.D. + 5 L.D.	Sep 14	139.9	6.86	20.4	5.4	4.69	7.4	9.2	10.2	12.1
1B	7 S.D. +10 L.D.	Sep 17	127.3	5.40	23.6	5.4	4.55	8.8	10.7	13.0	15.1
1C	7 S.D. +15 L.D.	Sep 19	93.3	3.26	28.6	6.1	4.66	8.7	11.1	13.5	15.0
1D	7 S.D. +20 L.D.	Sep 26	105.7	3.67	28.8	5.9	4.89	9.3	10.9	13.1	15.1
2A	14 S.D. + 5 L.D.	Sep 11	170.7	5.60	30.5	6.6	4.66	8.6	9.6	11.7	12.2
2B	14 S.D. +10 L.D.	Sep 17	88.3	3.93	22.4	4.8	4.95	8.3	9.5	11.3	11.9
2C	14 S.D. +15 L.D.	Sep 22	99.1	4.86	20.4	4.4	4.78	10.0	11.6	13.3	13.6
2D	14 S.D. +20 L.D.	Sep 27	100.3	4.40	22.8	5.3	5.00	10.3	12.1	14.0	15.3
3A	21 S.D. + 5 L.D.	Sep 11	147.1	5.40	27.2	6.5	4.5	8.7	10.0	12.1	13.1
3B	21 S.D. +10 L.D.	Sep 15	122.9	5.13	23.9	5.6	5.1	8.4	10.0	12.1	12.8
3C	21 S.D. +15 L.D.	Sep 21	121.5	5.80	20.9	4.7	4.9	8.3	9.1	10.9	11.4
3D	21 S.D. +20 L.D.	Sep 21	110.7	4.80	23.1	4.8	5.2	7.5	8.2	10.8	11.6
4A	28 S.D. + 5 L.D.	Sep 15	143.7	6.13	23.4	5.6	4.5	7.0	8.5	10.2	11.2
4B	28 S.D. +10 L.D.	Sep 15	151.4	5.20	29.1	5.7	4.8	11.4	12.8	14.4	15.3
4C	28 S.D. +15 L.D.	Sep 15	123.5	4.13	29.9	6.0	5.0	9.5	10.6	12.1	13.6
4D	28 S.D. +20 L.D.	Sep 15	129.3	4.33	29.9	6.4	5.0	8.6	9.1	11.6	12.8
5A	35 S.D. + 5 L.D.	Sep 10	162.4	4.87	33.4	6.5	5.0	8.9	10.0	11.5	12.4
5B	35 S.D. +10 L.D.	Sep 10	154.7	4.53	34.1	6.4	5.0	9.3	10.9	12.5	13.5
5C	—	—	—	—	—	—	—	—	—	—	—
5D	35 S.D. +20 L.D.	Sep 10	143.1	3.60	39.7	8.6	5.0	9.7	10.9	12.6	13.2
6	Check (continuous S.D.)	Sep 10	160.0	4.53	35.3	7.5	4.7	7.0	7.8	9.4	10.3
	Variety Chicago Pearl										
1A	7 S.D. + 5 L.D.	Sep 18	125.3	4.7	26.8	7.4	4.8	4.3	6.2	8.6	11.4
1B	7 S.D. +10 L.D.	Sep 27	114.2	4.6	24.8	7.1	4.9	7.9	10.2	15.4	19.2
1C	7 S.D. +15 L.D.	Sep 28	66.4	3.0	22.1	6.3	4.9	7.8	9.4	13.2	17.1
1D	7 S.D. +20 L.D.	Sep 28	48.1	1.7	28.8	6.4	5.0	6.9	8.4	12.5	15.8
2A	14 S.D. + 5 L.D.	Sep 18	95.5	3.5	27.6	8.7	4.2	2.5	4.5	6.7	8.2
2B	14 S.D. +10 L.D.	Sep 26	91.9	1.9	47.6	11.7	4.9	5.3	7.4	10.7	11.9
2C	14 S.D. +15 L.D.	Sep 27	39.5	1.4	28.3	6.7	5.8	6.4	9.0	11.7	12.9
2D	14 S.D. +20 L.D.	Sep 28	26.3	0.9	43.5	8.7	5.7	7.3	10.3	13.3	13.9
3A	21 S.D. + 5 L.D.	Sep 15	97.3	4.4	22.1	7.3	4.9	2.6	4.6	7.1	9.1
3B	21 S.D. +10 L.D.	Sep 26	63.1	2.5	25.0	7.7	4.8	5.1	6.8	9.2	10.7
3C	21 S.D. +15 L.D.	Sep 26	48.2	2.0	24.1	6.9	4.9	3.2	4.9	7.7	8.6
3D	21 S.D. +20 L.D.	Oct. 1	54.9	1.8	30.5	6.7	5.6	5.1	7.1	9.3	10.9
4A	28 S.D. + 5 L.D.	Sep 13	108.2	3.9	27.5	7.1	5.1	3.6	5.5	7.7	8.8
4B	28 S.D. +10 L.D.	Sep 11	90.9	2.2	41.3	9.4	5.1	4.7	6.9	9.4	11.2
4C	28 S.D. +15 L.D.	Sep 13	62.9	1.9	32.6	8.2	5.1	5.0	6.7	9.3	10.8
4D	28 S.D. +20 L.D.	Sep 13	69.1	2.0	34.6	10.1	5.1	5.1	6.7	9.2	11.1
5A	35 S.D. + 5 L.D.	Sep 13	70.7	4.4	16.1	7.3	4.6	3.2	4.4	6.4	8.2
5B	35 S.D. +10 L.D.	Sep 12	79.5	2.7	29.8	8.4	4.9	5.4	6.8	9.9	11.6
5C	35 S.D. +15 L.D.	Sep 13	73.9	3.4	21.7	5.7	5.0	4.0	5.2	7.3	8.5
5D	35 S.D. +20 L.D.	Sep 13	46.8	1.9	24.2	6.3	5.2	5.2	6.8	9.3	10.5
6	Check (continuous S.D.)	Sep 13	108.7	4.8	22.6	7.8	4.8	2.8	3.8	5.0	6.0

*Green weight is the weight of the stems cleaned of their lower foliage and ready to bunch for market. It is the marketable weight and not the total green weight.

†S.D. = short day, L.D. = long day.

ton and Chicago Pearl, which formed after one week of short days, flowered at the same time as those formed as the result of the second short day treatment started 15 or 20 days later than the first. The long day interval prevented further development of the top buds and the stimulus for their growth had been dissipated during the long day interval. When the short day treatment was resumed, these first buds again started to grow and more flower buds formed.

Princeton normally produces visible disc flowers in the center of several rows of rays. Five long days in the cycle had no obvious effect on the ratio of disc to ray flowers; this was also true when 4 or 5 weeks of short days were followed by any number of long days. A greater number of disc flowers than normal developed when the plants were given 10 long days after 7 short days. Fifteen or 20 long days after 7 short days increased the number of disc flowers even more than 10 long days. Fourteen short days followed by 10 or 15 long days gave similar results, while 20 long days after 14 short days gave almost no disc flowers. These were more double than those given no long day interval. Twenty-one short days followed by 10 long days also gave a few disc flowers while 21 short days followed by 15 and 20 long days gave more than a normal number of disc flowers. This tendency toward "singleness" occurs under normal conditions some years more than others. It is objectionable in commercial production and is explainable on this basis which is produced due to cloudy or clear weather.

Yellow Fellow was most single when given 7 short days followed by 20 long days and was most double when given 14 short days followed by 15 or 20 long days or 21 short days followed by 20 long days. Other treatments had no apparent effect on disc flowers. Mrs. Bulkley produced more disc flowers when given 20 long days after 7 short days than other treatments. Chicago Pearl produced two sets of buds accompanied by vegetative growth when given 5 short days followed by 10 or more long days. Other treatments produced only one set of buds.

Time of flowering was not affected, or was no more than 8 days later than continuous treatment, if plants were given 5 to 20 long days after 28 short days. When 21 short days were followed by long days, flowering was delayed by about two-thirds the length of the long day treatment. Flowering was delayed by two-thirds or more than the length of the long day treatment if 7 or 14 short days were followed by long days.

The weight produced was not consistent with the varieties in the various treatments. The long day interval usually increased the weight of Princeton and did not greatly affect it with Yellow Fellow. In most cases the greater the interval of long days in the series the greater the decrease in total weight in the variety Mrs. Bulkley and Chicago Pearl.

The number of stems per plant was in general increased by the long day interval on Princeton and Yellow Fellow and reduced on Mrs. Bulkley and Chicago Pearl. In all cases the trend was for a smaller number of stems per plant as the length of the long day treatment was extended. The weight per stem usually increased as the number of stems per plant decreased.

The number of buds per stem on Princeton was not affected by the long day interval and there were no consistent differences with Chicago Pearl. The number of buds per stem decreased on Mrs. Bulkley and Yellow Fellow with a long day interval.

In general the diameter of the terminal flower was affected very little by the treatment of Princeton. Flowers of Yellow Fellow were increased in size by any treatment and those of Mrs. Bulkley and

Chicago Pearl were larger in most treatments. The trend was for an increase in size of flower as the number of long days in the treatment increased.

The length of the peduncle of the top four flowers on the stem was in most cases increased as a result of the long day treatment. The trend was for a greater increase in length as the long day treatment was increased. The effect was usually somewhat greater if the long day treatment was started after one week than when started after a longer initial short day treatment. This effect allows the individual flower heads to stand apart more than normal and makes a better showing. It is especially desirable where the variety tends to produce the flower heads on short peduncles.

SUMMARY

It appears from the data that a long day interval of 5 to 20 days given after 28 or 35 days delayed the date of bloom by a maximum of 8 days in comparison with the continuous short day treatment. The size of flower was increased slightly and the individual flower heads were on longer peduncles, allowing the flowers to stand farther apart when the long day interval was given. The weight and number of stems per plant varied with the variety and treatment and no consistent effect was evident. As the number of stems per plant increased, the weight per stem usually decreased.

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Relation of Defoliation by Japanese Beetles and Drought to Frost Injury of American Elm

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THE American elm, *Ulmus americana* L. is ranked among the hardiest trees of the eastern and middle United States. Without this quality, it never could have become the most popular and valuable shade tree of this region. The tissues important to hardiness in trees are cambium, sapwood, and cortex, which are tender to frost in the active or immature stage. In hardy trees these tissues become very resistant to cold after maturity has been reached. While the American elm is known to be very hardy, occasionally it is caught in a tender active condition by frost and injured. Humphrey (1) reported extensive frost injury of cambium in this species, in Rockford, Illinois in 1912. This paper presents further evidence of the same phenomenon in American elm which appeared in the city of Washington during the summer of 1942, and includes an explanation of the factors involved, as well as directions for its prevention.

The injuries were found more or less widespred in a planting of 453 American elms in the Mall of the National Capital Parks. The trees were 4 to 10 inches in trunk diameters and had been established 4 to 9 years. Their vigor varied from fair to high, and on the average was good. The site was level and well exposed, and the ground was covered with sod. Fifteen trees were injured, of which two died to the ground, while the others recovered.

The two destroyed trees had trunk diameters of 6 and 9 inches and were of good and high vitality, respectively. Both trees leafed out normally in the spring and produced a full crop of average sized leaves. On May 15, however, the 6-inch tree was observed in a general wilt, its leaves turning yellow to brown, and on June 22 the initial stages of the same condition became apparent in the 9-inch tree. Examination of the wilted branches of the crown for evidence of vascular wilt disease discoloration, when wilting was first noticed, gave negative results. Exposure of the sapwood at widely separated points on the trunk, however, revealed extensive brown discoloration in the superficial sapwood and inner cortex. Both trees began dropping their foliage within a week after wilting was first discovered.

The 6-inch and 9-inch trees were felled and further examined on June 4 and July 2, respectively. Both trees were in about the same condition. Defoliation was 75 to 90 per cent complete. The sapwood and inner bark of the main trunks were greatly discolored superficially, and were fermenting very noticeably, except for a few small scattered patches of live tissue; while similar tissues in the top, roots, and trunk collar below the ground line remained clean. The separation line between brown discoloration in the trunks above the ground line and white healthy tissue below was very sharp and striking, as is illustrated for the 9-inch tree in Fig. 1.

No further cases of elm wilting occurred in the Mall during the rest

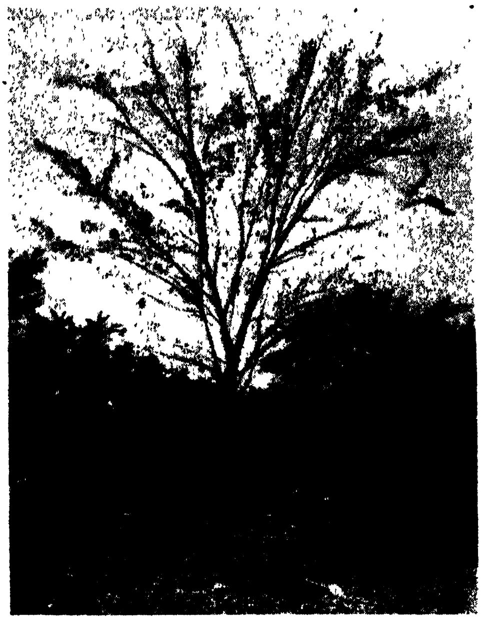

FIG. 1. American elm destroyed by frost. Soil excavated from base of trunk, and bark removed from trunk above and below ground line shows sapwood discolored from frost injury only above the ground line, the same tissue protected underground remaining clean and healthy.

of the summer, but an exploratory survey on July 3, 1942, showed other manifestations of apparently the same injury. Heavy sheets and strips of old bark were noticed separating from the lower trunks in several trees, and new bark replacing the old. A complete survey of the elms for similar symptoms at the end of the season revealed 13 cases. The injuries were confined entirely to the trunks, particularly to the basal region, within 3 feet of the ground. In respect to injury around the trunk, three cases were injured 100 per cent; two, 75 per cent; four, 50 per cent and four, 10 per cent. In every case, sapwood which had lost its original bark was re-covered 80 per cent or more by vigorous layers of new bark of remarkable thickness.

The injuries described were attributed to frost on the basis of experimental demonstrations of frost phenomena in trees by Sorauer (2), Chandler (3), and Day and Peace (4). Furthermore, the sharp termination of the discoloration in the trunks at the ground line was regarded as substantial evidence that the phenomenon was related to frost, the ground having acted as a blanket in protecting the parts underneath. The absence of injury in the crowns seemed accountable to earlier maturity as similarly found by Chandler (3) in apple. The difference between the permanent and temporary injuries apparently depended on the kind of tissue caught by frost in a tender immature condition. In the permanent injuries the cambium was tender, and possibly also the cortex and sapwood, while in the temporary injuries it was only the cortex. The cambium, proving hardy in the latter cases, was thus able to replace the destroyed cortex.

The localization of the injury in the trunks placed the time of the frost attack in the fall, for that seems to be the only time of the year that the trunk may be relatively tender as compared to the top, according to Chandler's (3) studies of frost injury for different seasons in apple.

When normally hardy trees are injured by frost in the fall, the damage can usually be ascribed to early frost or stimulated late growth. An inspection of the United States Weather Bureau reports for Washington during the autumn of 1941 showed that no early frost was involved, for the first killing frost did not arrive until November 13, which was nearly 3 weeks later than usual; nor had any stimulation of growth come from such usual causes as a wet fall, late applications of active nitrogen fertilizer, or cultivation, for the fall had been exceptionally dry, and it was known that the trees had not been fertilized or cultivated late. It was recollected, however, that many of the trees had been almost totally stripped of foliage by an unusually heavy attack of Japanese beetles, *Popillia japonica* Newm., in the latter part of June and through July, which was followed closely by a drought starting at the beginning of August and continuing until December 4. The United States Weather Bureau records for Washington, in that period, showed the August precipitation to be 1.92 inches; September, .53 inch; October, 1.08 inch; and November, .81 inch as compared to their respective normals of 4.01, 3.24, 2.84 and 2.37 inches.

Producing a second crop of leaves in the face of the drought, with more than half of the growing season gone, unquestionably was a severe task for the trees. How successfully the trees met this problem depended on their ability to produce a second crop of leaves to maturity, without at the same time prolonging their active growth period into the frost season. Some of the trees evidently were unable to meet this test and consequenly when frost came were caught in an unripened condition and injured. Chandler (5) also has observed in fruit trees that defoliation from any cause as by leaf-eating insects or spray burning, was an important factor predisposing to frost injury.

Control of frost injury to immature tissue in trees depends entirely on preventative measures, namely, those which provide normal thrifty growth. To accomplish this, it is important to provide good growing conditions, protection of the foliage from leaf-destroying insects or foliage diseases by spraying when significant damage is threatened, and avoidance of stimulation toward the close of the growing season or prior to resumption of growth in the spring.

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The Influence of Flower Removal on Gladiolus Corm Development[1]

By A. N. Roberts and J. A. Milbrath, *Oregon State College, Corvallis, Ore.*

THE effects of flower spike removal on the size of the vegetative corm produced by the gladiolus has been studied at the Oregon State Agricultural Experiment Station. At the inception of these studies which covered a 3-year period, 1940–43, the accepted practice of removing flowers of gladiolus at the time of bloom was for one of two purposes: for either sale as cut flowers, in which case considerable flower stalk and leaves might be removed, or merely the removal of the flower spike for the purpose of diverting food and water to the corm to increase its size. The following study was made to determine what relationship exists between flower spike and corm development in gladiolus, and to what extent flower removal might influence the size of the vegetative corm. Factors considered as having possible influence on the effects of flower removal were: varietal variations such as season of bloom and variations in seed production, stage of flower spike development at time of removal, and the amount of flower stalk and leaves removed with the flower.

METHODS AND PROCEDURE

Preliminary studies during the 1940 season consisted of replicated plots of the varieties Minuet and Dr. Bennett. Uniform lots of commercial planting stock of No. 5 size were planted to obtain consistent flowering. The purpose of this study was to determine the influence, if any, of the flower spike on corm production by comparing plots whose flower spikes were removed at various stages of development, as against plots where the spikes were left to develop to maturity. Also, plots were included where the flowers were cut as for the florist trade, taking some leaves and considerable flower stalk. The treatments and results are summarized in Table I.

TABLE I—INFLUENCE OF FLOWER REMOVAL ON CORM SIZE IN GLADIOLUS, 1940

Time of Flower Removal	Mean of Average Corm Weights of Four Replications (Gms)			
	A-Series	B-Series	A-Series	B-Series
	Minuet Variety		*Dr. Bennett Variety*	
Emergence from sheath	46.2	51.3*	41.1	47.6*
First color appeared	40.7	39.4	37.6†	44.1
First floret opened	39.2†	40.6	34.3†	42.3
First floret withered	34.1†	42.8	31.0†	38.9
Half floret withered	33.1	41.5	29.6†	39.2
All florets withered	31.2†	39.8	30.0†	39.7
Check—Florets only removed	44.2	41.2	39.8	38.9
Check—No flowers removed	45.9	42.6	45.2	39.2
Difference necessary for significance	7.13		6.12	

*Those significantly larger than uncut plots.
†Those significantly smaller than uncut plots.
A-Series—Cut deep, including most of spike as for cut flowers.
B-Series—Cut shallow, just under lowest floret.

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DISCUSSION

Comparing the average corm weights produced by the various flower removal treatments in the shallow-cut series (Series B) with those of the uncut plots, only one practice is significantly beneficial over the uncut plots. When the flower spike was cut as soon as it emerged from the sheath and before any color appeared, the size of the corm was significantly larger. This would seem to indicate that any substantial benefit to be derived from flower removal would result only when the spike was removed before it becomes fully developed. Any saving in storage materials for the corm is apparently lost by delaying the flower removal. Removal after the spike has developed far enough to show color is apparently too late to divert any great amount of materials for storage in the corm. It is not feasible for the growers to remove the spikes at this early stage because of the necessity for roguing out any mixtures on a color basis.

These results also show the detrimental effect on corm size of harvesting cut flowers for the florist trade. The leaf removal that is necessary in cutting the long stems for cut flowers results in smaller corm size. An average loss of from 12 to 18 per cent in corm weight resulted from this treatment. This reduction in corm size is in direct proportion to the amount of leaf surface removed.

Nineteen varieties of gladiolus with blooming dates varying from 85 to 129 days from planting were selected for the 1941 plots. Each treatment was replicated four times and each replication was composed of 50 No. 5 corms of each variety. The flowers were cut at two-day intervals with uncut check plots left to flower and seed. The date of blooming and the amount of seed produced by each variety was recorded to determine the influence of these factors on the effects of flower removal. The treatments and an analysis of the results are given in Table II.

These data indicate that with the above varieties of gladiolus there is very little advantage in flower removal at any time after the flowers develop far enough to show color. There is some gain in corm size from flower removal, but the amounts are insignificant in most cases with the exception of the very late-flowering varieties. These varieties, such as Albatros, Bagdad, and Betty Nuthall, are decidedly benefited by flower removal at any stage and even more so in the early stages of flower spike development. The midseason varieties vary in their response to flower removal. Some show significant increases in corm size if the flowers are removed, while others do not. The differences are not great enough to be of much significance, when these varieties are considered as a group. Some of the very early varieties, such as Pelegrina, Polar Ice, and White Butterfly, are not benefited by flower removal, and the corms are reduced in size when any of the leaves are removed with the flower. Time of flowering may be of considerable value in determining whether or not the flower should be removed.

The effects of flower removal could not be correlated with the different amounts of seed produced by the various varieties.

In 1942 these studies were continued in commercial plantings, where the growers followed their standard method of flower removal. In these

TABLE II—INFLUENCE OF FLOWER REMOVAL ON CORM SIZE IN GLADIOLUS, 1941

Variety	Period of Bloom (Days from Planting)	Means of Av. Corm Weights (Gms)					Difference Necessary for Significance	Seed Production
		Not Cut	Cut When First Color Appeared	Cut Full Bloom	Cut Flowers Withered	Cut Deep for Cut Flowers		
White Butterfly...	85	27.5	24.3	22.6	23.9	14.7	2.33	Heavy
Polor Ice	91	34.1	35.4	27.6	30.9	19.6	a	None
Pelegrina	98	26.2	23.9	24.1	25.6	18.2	3.03	Light
Red Phipps .	98	19.8	23.2	25.8*	24.4*	19.6	4.06	Heavy
Maid of Orleans	98	25.9	29.8	30.3*	29.2	24.5	4.50	Heavy
King Arthur ...	102	39.9	28.2	43.9	43.0	30.9	5.18	None
Dr. Moody. . .	102	27.2	29.0	31.2*	29.3	25.5	3.02	Light
Amador	102	41.7	43.0	45.7	48.5*	35.5	5.55	Medium
Debonaire . .	105	44.1	43.7	44.9	49.3*	38.0	4.94	Medium
Golden Cup .	105	35.8	37.8	38.2	36.6	30.6	3.37	Light
Sonatine	105	32.7	35.8*	35.9*	35.4*	28.7	0.89	Light
Picardy—1	112	32.4	37.7	35.9	36.6	32.0	5.40	Light
Picardy—2 .	112	38.3	42.2	41.3	43.3	35.0	8.17	Light
Giant Nymph. .	112	22.0	30.7*	28.2*	30.9*	22.3	a	Heavy
Mildred Louise .	112	24.2	28.2	29.3	28.3	23.6	6.18	Light
Commander Koehl	112	24.1	28.1	27.2	27.0	22.6	4.60	Medium
Albatros . . .	116	27.2	37.6*	33.4*	30.3	30.3	4.82	Light
Bagdad	123	28.8	36.1*	33.2	32.2	32.0	6 08	Light
Betty Nuthall	129	15.3	24.6*	22.0*	17.8	18.4	3.83	Medium

a/Not sufficient replications.
*Significantly larger than plot not cut.

plantings a portion of certain varietal blocks was left to mature their flowers for comparison. At harvest time four random samples of 50 corms each were taken from each lot. The samples were cleaned, sized and weighed. These records are given in Table III.

Although the above results do not include many varieties due to the failure of certain growers to cooperate in leaving the uncut plots, the consistency of the results obtained in different plantings is quite sig-

TABLE III—GLADIOLUS FLOWER REMOVAL STUDIES, 1942

Grower	Treatment of Flowers	Mean Average Corm Wt. of Four Replications (Gms)	Error	Per Cent of Various Sizes of Four Replications						
				Jumbo	1's	2's	3's	4's	5's	6's
			Minuet							
1	Removed	24.1	± .5148	3	32	47	17	1	—	—
1	Not removed	21.9	±1.1325	–	35	44	20	1	—	—
2	Removed	19.9	±1.4309	–	28	45	24	3	—	—
2	Not removed	16.9	±0.2693	–	23	37	36	4	—	—
			Charles Dickens							
1	Removed	12.9	±0.9937	–	9	30	52	7	2	—
1	Not removed	15.8	±1.0712	–	18	39	34	8	1	—
2	Removed	20.5	±1.2389	1	28	43	20	6	2	—
2	Not removed	20.6	±0.8441	1	28	47	21	3	—	—
3	Removed	30.0	±0.5979	2	70	23	4	1	—	—
3	Not removed	32.6	±1.0464	1	73	19	7	—	—	—
			Bennett							
1	Removed	13.6	±0.7399	–	3	26	54	17	—	—
1	Not removed	11.7	±1.0037	–	—	17	45	38	—	—
			Polar Ice							
1	Removed	15.6	No	–	11	43	29	14	3	—
1	Not removed	15.5	Replication	–	12	45	24	13	6	—

nificant. These results coincide with the findings of the trials of the previous two years, and indicate that the grower gains very little either in size or weight of corms by removing the flowers.

CONCLUSIONS

The results obtained in these various experiments indicate that flower removal as a means of increasing corm size in gladiolus is not consistent with all varieties and the gain is only slight with most varieties. There seems to be no advantage to corm production in removing the flowers of early blooming varieties, and if any foliage is removed, it may be decidedly detrimental. There is considerable increase in corm size from flower removal of very late-blooming varieties. The mid-season blooming varieties are variable in their response to flower topping with no outstanding gains from removing the flower heads.

Loss in corm size due to cutting flowers for florist trade is in direct proportion to the amount of leaf surface removed. Care in cutting the spikes will reduce this loss to a minimum.

Studies on the Propagation of Certain Broadleaf Evergreens With Special Reference to Leaf-Bud Cuttings and Root-Inducing Substances[1]

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THE results obtained by Skinner (1) with rhododendrons, Stoutemyer *et al* (2) with raspberries, Watkins (3) with tropical broadleaf evergreens, and those of the author (4) with *Ligustrum ovalifolium* suggested the possibility of leaf-bud cuttings as a commercial method of propagating broadleaf evergreens.

Skinner (1) reported leaf-bud cuttings of rhododendrons as having shown a distinct advantage over stem cuttings from the standpoint of a higher percentage of rooting and of a shorter time requirement for the production of a sizeable plant.

Stoutemyer (2) found that single and two-eye stem cuttings of black raspberry plants invariably rotted in the propagation bench but that "leaf-bud" cuttings were successful. He also mentioned the excellent results obtained in the propagation of a number of greenhouse plants using leaf-bud cuttings, and referred to the work of Hunter in the propagation of certain types of citrus by this method.

Watkins (3) successfully propagated certain varieties of Azalea, Buginvillaea, Codiaeum and Hibiscus by this method in Florida.

These studies allude to the possibility of a wide application of this method of propagation in nursery practice, particularly for broadleaf evergreens.

A survey was made by questionnaires to southern nurserymen to determine the methods they used in the propagation of a representative list of broadleaf evergreens, inquiring particularly if they used the leaf-bud cutting method or root stimulating substances. The replies received presented, rather consistently, the opinion that root-inducing substances were of no particular economic value since their use rarely increased the percentage of rooting or shortened the period required for rooting sufficiently to justify their use. Most of them found the dust treatment more convenient than the solutions which required an extra period of handling. The survey was made in 1939 at which time root-inducing substances were relatively new to the market. There are now, of course, many indications of a change of attitude on the part of commercial growers to these substances. None of the nurserymen reported propagating commercially by the leaf-bud method.

PROCEDURE

In December, 1939, cutting material of the broadleaf evergreens used were furnished by Fruitland Nurseries, Augusta, Georgia, Henry Kohankie & Sons, Painesville, Ohio, Le Mac Nurseries, Hampton, Virginia, and Overlook Nurseries, Crichton, Alabama. Due to the limited amount of most of these materials, only 25 leaf-bud and 10 stem cuttings could be included in each of the six treatments given, namely,

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[1] These experiments were conducted at Cornell University in consultation with Dr. A. M. S. Pridham of the Department of Floriculture and Ornamental Horticulture.

Hormodin I, II and III, and Rootone 1 and 10, and the check. In a few cases, however, additional treatments were given when the amount of material permitted and consisted of various concentrations of indolebutyric acid in solution ranging from 50 mg/1 to 500 mg/1, of cuttings taken according to the age of the wood, and of leaf-bud cuttings taken from the terminal and lateral positions.

Treatments in each case followed the regular commercial procedure of dipping the moistened base of the cuttings into the dust or of soaking the base in the solution which had been prepared from crystalline chemicals.

The cuttings were inserted in an acid peat and sand mixture in closed grafting cases and supplied with a thermostatically controlled electric coil for bottom heat which maintained the temperature of the media at 80 degrees.

TABLE I—CALENDAR OF OPERATIONS

Material	1939 Inserted	1940 Removed
Camellia japonica (liquid)	Dec 20	Feb 20
(dust—leafbud..	Dec 5	Feb 28
Stem	Dec 5	Feb 28
Ilex cornuta (leafbud)	Dec 25	Feb 20
Stem	Dec 25	Feb 20
Ilex cornuta burfordi (leafbud)	Dec 22	Feb 20
Stem	Dec 22	Feb 20
Ilex crenata microphylla	Sep 20	Nov 15
Ilex integra (leafbud)	Dec 23	Feb 28
Stem	Dec 23	Feb 28
Ilex latifolia (leafbud)	Dec 5	Feb 20
Stem	Dec 5	Feb 28
Ilex opaca (liquid, leafbud)	Dec 15	Mar 6
Liquid, first test	Sep 18	Oct 15
Dust, leafbud	Dec 15	Mar 6
Stem, first test	Sep 20	Nov 15
Ilex pernyi (stem)	Dec 23	Feb 28
Myrica cerifera (leafbud)	Dec 15	Jan 21
Osmanthus fortunii (leafbud)	Dec 5	Feb 28
Stem	Dec 5	Feb 28
Osmanthus fragrans (leafbud)	Dec 21	Feb 20
Stem	Dec 21	Feb 20
Osmanthus ilicifolius (stem)	Dec 21	Feb 20
Photinia glabra (leafbud)	Dec 15	Jan 21
Stem	Dec 15	Jan 21
Photinia serrulata (leafbud)	Dec 15	Feb 20
Stem	Dec 15	Feb 20
Prunus carolinianum (leafbud)	Dec 15	Mar 6
Stem	Dec 15	Jan 21
Prunus laurocerasus (leafbud)	Dec 22	Feb 20
Stem	Dec 22	Feb 20
Viburnum rhytidophyllum (leafbud)	Sep 18	Nov 15
Stem	Sep 18	Nov 15

After various lengths of time as reported in Table I these cuttings were lifted and photographed and data taken relative to the number rooted, quality and quantity of roots, and injury due to root-inducing substances. The following scale was set up for rating each of these cuttings:

+1—Roots poorly developed without evident injury
+2—Roots well developed without injury
+3—Roots prolific without injury

−1—Injury mild regardless of root development
−3—Injury serious regardless of root development
−5—Injury resulting in death of the cutting

The evaluation thus given in the tables that follow for any lot of cuttings is the total aggregated by the individual cuttings. They were then potted for further observation and study.

TABLE II—Percentage of Leaf-bud and Stem Cuttings Rooted and Evaluation of Their Rooting at the Time of Their Removal from the Rooting Media

Material	Check		Rootone				Hormodin						Totals
			1		10		1		2		3		
	(Per Cent)	(Eval)	(Per Cent)	(Eval)	(Per Cent)	(Eval)	(Per Cent)	(Eval)	(Per Cent)	(Eval)	(Per Cent)	(Eval)	(Eval)
Camellia japonica													
L	44	23	80	40	84	50	72	37	88	56	88	53	359
S	—	—	100	27	110	27	100	26	100	28	—	—	108
Ilex cornuta													
L	0	0	36	21	0	0	—	—	36	27	24	18	66
S	20	4	100	28	100	26	100	20	100	28	100	24	130
Ilex cornuta Burfordi													
L	68	17	100	46	12	6	88	41	76	41	64	30	181
S	100	16	100	27	100	29	—	—	100	30	100	30	132
Ilex integra													
L	0	0	36	10	16	4	88	40	76	32	84	42	168
S	0	0	60	7	60	12	90	19	80	18	100	18	74
Ilex latifolia													
L	40	19	16	8	44	27	52	19	60	35	56	27	135
S	20	6	100	29	100	24	90	25	100	29	90	27	140
Ilex opaca													
L	60	24	28	14	4	3	64	37	36	22	44	27	127
Ilex pernyi													
S	10	2	90	21	30	7	70	10	30	5	50	11	56
Myrica cerifera													
L	56	22	36	14	8	3	36	17	8	3	4	0	59
Osmanthus fortunii													
L	—	—	16	6	12	3	20	9	24	10	32	13	41
Osmanthus fragrans													
L	32	8	24	9	8	1	12	5	28	9	36	13	45
S	40	9	100	22	90	18	60	10	90	16	100	21	94
Osmanthus ilicifolius													
L	56	23	56	20	4	1	36	18	20	8	36	15	85
S	80	13	80	10	70	9	80	10	60	11	100	19	72
Photinia glabra													
L	0	0	20	7	4	1	40	10	60	18	—	3	39
S	16	1	16	1	16	1	16	1	32	3	16	2	9
Photinia serrulata													
L	0	0	44	18	16	8	24	7	36	17	64	37	87
S	50	5	30	3	30	5	60	8	70	13	60	9	43
Prunus carolinianum													
L	12	5	56	32	56	34	56	33	88	45	56	35	184
S	10	2	30	4	50	7	20	3	20	3	30	5	24
Prunus laurocerasus													
L	60	36	40	22	16	6	—	—	20	13	20	11	88
S	70	8	100	17	80	18	90	15	60	10	70	11	79
Totals		237		463		329		420		530		501	

In June, 1940, the plants were measured for shoot growth and subsequent root development within the pots. The later measurements were based on observation of the comparative amounts of roots visible on the outside of the ball of earth when the plants were knocked out of the pots. Since the majority of roots in potted plants develop on the outside it was believed that those evident would indicate roughly the total quantity developed. The following scale was set up for rating these roots:

+ 0—Cuttings not rooted to date or dead

+ 1—Cuttings rooted but no roots evident on the surface of the ball

+ 2—Roots sparce, very few evident
+ 3—An average amount of roots evident according to the species
+ 4—Rooting slightly better than the average
+ 5—Rooting very prolific, plant pot bound

The rating thus given in the tables that follow for any lot of cuttings is the total aggregated by the individual plants.

TABLE III—PERCENTAGE OF LEAF-BUD AND STEM CUTTINGS PRODUCING SHOOT GROWTH AND THE TOTAL AMOUNT OF SHOOT GROWTH IN CENTIMETERS PRODUCED BY INDIVIDUAL LOTS BY JUNE 10, 1940

Material	Check		Rootone				Hormodin						Totals
			1		10		1		2		3		
	(Per Cent)	(Cms)	(Per Cent)	(Cms)	(Per Cent)	(Cms)	(Per Cent)	(Cms)	(Per Cent)	(Cms)	(Per Cent)	(Cms)	(Cms)
Camellia japonica													
L.	86	113	75	159	80	160	86	155	95	195	71	106	888
S.	—	—	88	129	100	111	90	140	100	172	—	—	552
Ilex cornuta													
L	12	2	11	4	—	—	—	—	0	0	14	13	19
S	0	0	12	12	0	0	25	3	10	8	12	7	30
Ilex cornuta Burfordi													
L	0	0	0	0	0	0	0	0	0	0	0	0	0
S	0	0	33	49	44	64	11	9	33	33	11	13	168
Ilex integra													
L	—	—	30	20	60	15	85	110	50	60	66	76	281
S	0	0	27	60	60	51	33	69	50	87	83	111	378
Ilex latifolia													
L	0	0	7	1	0	0	7	2	25	11	0	0	14
S	25	6	80	56	70	46	40	16	37	30	77	59	213
Ilex opaca													
L	12	7	0	0	0	0	25	9	0	0	0	0	16
Ilex pernyi													
S	100	23	100	63	100	12	100	30	100	20	100	74	222
Myrica cerifera													
L	—	—	—	—	—	—	—	—	—	—	—	—	—
Osmanthus fortunei													
L	—	—	100	18	0	0	66	14	100	40	100	42	124
S	66	25	100	34	100	26	70	34	90	83	100	49	251
Osmanthus fragrans													
L	70	79	60	65	18	14	36	19	80	76	78	67	320
S	50	43	100	227	80	119	80	59	88	161	100	173	782
Osmanthus ilicifolius													
L	94	73	100	62	100	5	84	57	100	26	100	41	264
S	96	455	100	160	100	108	100	196	100	150	100	164	1233
Photinia glabra													
S	0	0	50	38	100	30	60	26	75	48	100	16	158
Photinia serrulata													
L	20	12	100	69	50	4	33	28	44	55	50	20	188
S	100	55	100	19	80	72	100	50	—	—	100	108	304
Prunus carolinianum													
L	100	9	64	60	57	31	79	62	80	66	40	28	256
S	50	26	100	61	100	70	66	16	100	18	70	52	243
Prunus laurocerasus													
L	100	72	100	71	100	37	100	97	100	46	100	38	361
S	100	132	100	39	100	19	100	43	100	13	100	37	283
Totals		1132		1476		994		1244		1398		1294	

DISCUSSION OF RESULTS AND CONCLUSIONS

The use of dusts in the application of root stimulating substances to cuttings was found more convenient than liquid applications by the nurserymen contacted through surveys. During this experiment, no distinct advantage was found for dust over liquid applications relative

TABLE IV—The Average Root Growth per Individual Plant in Lots of Leaf-bud and Stem Cuttings by June 10, 1940 (Evaluation After an Arbitrary Scale of Points)

Material		Check	Rootone		Hormodin		
			1	10	1	2	3
Camellia japonica	L	2.46	2.04	2.45	1.90	2.60	2.47
	S	—	3.12	3.00	3.00	3.40	—
Ilex cornuta	L	1.37	1.44	—	—	1.33	1.12
	S	2 00	3.25	3.30	3.50	3.10	2.75
Ilex cornuta Burfordi	L	2.50	3.00	2.66	2.94	3.00	3.08
	S	3.66	4.00	4.00	3.66	3.77	4.00
Ilex integra	L	0.00	2.00	2.00	2.28	2.00	2.22
	S	0.00	3.11	2.22	3.25	3.00	3.66
Ilex latifolia	L	3.37	3.33	1.33	2.64	3.35	4.00
	S	3.33	4.11	4.00	4.20	4.12	4.45
Ilex opaca	L	4.00	3.66	4.00	3.25	3.30	3.36
Ilex pernyi	S	2.00	2.33	2.00	2.66	2.50	2.75
Myrica cerifera	L	—	—	—	—	—	—
Osmanthus fortunii	L	—	2.25	2.00	2.50	2.28	2.14
	S	2.00	2.50	2.75	2.71	2.70	2.80
Osmanthus fragrans	L	2.00	1.78	1.45	1.81	2.13	2.08
	S	2.33	3.11	3.10	2.40	2.40	2.40
Osmanthus ilicifolius	L	2.00	2.00	2.00	1.75	1.80	1.77
	S	2.80	2.30	2.25	2.90	2.55	2.60
Photinia glabra	L	—	—	—	—	—	—
	S	2.00	3.50	5 00	3.00	4.00	5.00
Photinia serrulata	L	0.50	2 11	2.50	1.40	2.22	2.00
	S	3.00	4.50	2.40	3.00	—	2.66
Prunus carolinianum	L	3.66	3.44	3.43	3.18	3.43	3.60
	S	3.25	4.66	5 00	3.75	1.55	2.70
Prunus laurocerasus	L	4.82	4.60	5.00	4.50	4.80	4.75
	S	4.80	5.00	5.00	4.84	5.00	4.50

TABLE V—The Total Amount of Root Growth Produced June 10, 1940 by Leaf-bud and Stem Cuttings Growing in Pots by June 10, 1940 (Evaluation After an Arbitrary Scale of Points)

Material		Check	Rootone		Hormodin			Totals
			1	10	1	2	3	
Camellia japonica	L	37	49	49	40	60	52	287
	S	—	25	30	30	34	—	119
Ilex cornuta	L	11	13	—	—	8	8	40
	S	6	26	33	14	31	22	132
Ilex cornuta Burfordi	L	50	75	8	56	60	37	286
	S	22	36	36	33	34	36	197
Ilex integra	L	—	26	10	48	44	40	168
	S	0	28	20	26	21	22	117
Ilex latifolia	L	27	50	4	37	57	56	271
	S	10	37	28	21	33	40	169
Ilex opaca	L	52	22	4	26	33	37	174
Ilex pernyi	S	10	21	4	8	5	22	70
Myrica cerifera	L	—	—	—	—	—	—	—
Osmanthus fortunii	L	—	9	14	15	16	15	59
	S	6	10	11	19	27	14	87
Osmanthus fragrans	L	27	41	16	20	32	27	163
	S	14	28	31	12	21	21	127
Osmanthus ilicifolius	L	29	28	2	21	9	16	102
	S	70	23	18	29	23	26	189
Photinia glabra	L	—	—	—	—	—	—	—
	S	2	21	10	15	16	5	69
Photinia serrulata	L	10	19	5	18	51	8	111
	S	9	9	12	9	—	16	55
Prunus carolinianum	L	8	38	24	35	49	36	190
	S	13	26	25	15	13	19	111
Prunus laurocerasus	L	53	46	25	111	24	19	278
	S	48	20	20	29	5	18	140
Totals		514	847	428	688	706	614	

to the mechanics of the application alone. Whereas the preparation of the solution might be inconvenient for the nurseryman, no difficulty was experienced in the laboratory. The handling of cuttings required about the same amount of time in either treatment. In order to obtain a more even application, dust-treated cuttings must be dipped in smaller lots, involving more handling of the individual cuttings. Larger numbers of cuttings may be treated together in solutions. (The number of cuttings that could be treated together in the container would be modified by the amount and texture of the leaves).

In regard to the amount of dust adhering to cuttings, no experimental evidence is at hand to show the influence that quantity of dust might have. The results of previous experiments (4) suggest that the quantitative factor of the root-inducing chemical has a very definite influence on the amount of roots produced. However, results to be reported further in this paper will point out the advantage of *any* treatment within the tolerant range of the plant over the check plants in the quantitative and qualitative rooting as well as the time required, and subsequent shoot growth. The amount of significance that can be attached to this factor in reference to commercial production cannot be definitely stated, but further experiments might be initiated to determine the influence of the amount of the dust per cutting on the results.

The rooting of cuttings treated with dusts differed from that of cuttings treated with solutions. In the former case, the roots were usually longer and more branched. Although the roots produced by these two treatments were strikingly different in appearance, no anatomical studies were made to determine the extent of this difference or its significance. However, the differences were superficially studied later from a performance standpoint. The average rooting for the two treatments, dusts and liquids, for Camellias (solutions up to 150 mg/1 of indolebutyric acid) is as follows:

Solutions (average per treatment).......23 rooted......37 rating
Dusts (average per treatment)..........20.6 rooted ....47.2 rating

This indicates a higher percentage rooted in the solution-treated lots but a larger amount of roots in the dust-treated lots. One might question if this lower rooting might be due to lack of uniformity of application of the dust.

Subsequent measurements revealed a greater amount of roots as well as shoot growth among the dust-treated cuttings. This advantage is probably a result of the initial advantage in root development. The importance of this should be recognized by nurserymen in commercial production. Bud inhibition was greater among the cuttings treated with solutions for most of the species tested. With Camellias the maximum shoot growth of 105 centimeters and 109 centimeters for 100 mg/1 and 150 mg/1 solutions of indolebutyric acid respectively is far less than the 155 centimeters and 195 centimeters of shoot growth for the Hormodin I and II respectively or for the 159 centimeters and 160 centimeters of shoot growth for Rootone 1 and 10 respectively. Shoot production was conditioned by bud inhibition, root production and cultural treatments. Immediate growth of the shoot is necessary for either leaf-bud or stem cuttings to be commercially profitable. Cuttings of *Ilex opaca* which grew at once were from three to five times as large as those that started growth one year later, measurements being taken August 11, 1941. By this date, shoot growth had taken place in practically all species 100 per cent.

Leaf-bud cuttings compared favorably with stem cuttings in most of the species tested. An important observation was that for a given amount of cutting material the subsequent total shoot growth was much greater for leaf-bud cuttings than for stem cuttings, this advantage even being shown with an equal number of cuttings for some of the species. Camellia stem cuttings treated with Rootone 1 produced an average of 12.9 centimeters as shown in Table III. The leaf-bud cuttings produced an average shoot growth of 6.4 centimeters. Since a conservative minimum of five leaf-bud cuttings might have been taken from the same amount of material required to make one stem cutting, a total of five times 6.4 centimeters or 32.0 centimeters of shoot growth might have been obtained rather than 12.9 centimeters.

With Osmanthus leaf-bud cuttings, the abscission layer formed in many cases before and after rooting had taken place. Consequently the base of the cutting fell off with a reduction in the reported number rooted. An experiment might be initiated using solutions of Naphthyleneacetic acid to determine if the abscission layer can be prevented from forming. The reports on *Myrica cerifera* and *Pyracantha Gibbsii* are incomplete since many of the cuttings rotted either before or after rooting had taken place.

The shoot growth on the cuttings of *Camellia japonica* treated with dust was rapid through the growing seasons of 1940 and 1941. The color of the leaves was a bright green. By August 11, 1941, only 6 plants out of 163 had formed flower-buds. The shoot growth on the cuttings treated with solutions was not nearly so rapid as that of the dust-treated cuttings. The color of the leaves was distinctly a darker green. By August 11, 1941, more than 100 of the 165 plants had formed flower-buds. This was evidence of a higher carbohydrate content perhaps induced by some modification in either the stem or the root of those cuttings treated with solutions. Attention has already been directed to a less prolific root system on the cuttings treated with solution. A shoot/root ratio which favors the roots would result in more nitrogen intake and thus encourage vegetative growth. A shoot/root ratio which favors the shoot would result in a greater carbohydrate content and thus encourage flower-bud formation. Recent investigators have pointed out that often root-inducing substances cause certain anatomical deformations in the stem or root. That such deformations are promoted by the solution treatment rather than the dust treatment was not ascertained. Attention has also been directed to a superficial difference in the morphology of the roots resulting from the two treatments. It might well be assumed that these differences were also anatomical and functional in causing physiological differences in distal portions of the plants.

The shoot/root ratio which was found narrower for the cuttings treated with solution than for those treated with dust likewise was found to narrow inversely with the concentration of the solution. The inhibition of buds was directly proportional to the concentration. It might be assumed that the substance which induces rooting continues to act as an irritant, mobilizing elaborated materials within the plant for root metabolism. This would tend to inhibit the ascent of nitrogen to the shoot since it would be utilized in protein synthesis in the roots. Thus the situation may tend to perpetuate itself, resulting in a hardened condition in the shoot due to a lack of nitrogen to carry on growth.

Some consideration might be given the fact that substances in solution would tend to become more systemic than those in dusts since the solutions would be taken in through the xylem to the distal portions of the cutting. The amount of the substance that dissolves and finds its way into the xylem on dust-treated cuttings has not been clearly determined. Neither is it clear as to whether the dust that adheres to the side of the cutting rather than the base is active in inducing rooting. It would thus appear that the matter of absorption needs to be given attention. Particularly, the role of the several tissues exterior to the xylem would need study. If the phloem were affected directly, it might explain the less deleterious effects of the more or less local dusts against the more or less generally dispersed solution.

Since the intake of minerals is a physiological process in plants, any irritant that seriously interfered with normal metabolism might also disturb the physiology of mineral absorption. This condition would result in a low nitrogen content. Likewise, the physiology of transport might be inhibited. These factors interacting with the tendency of roots to utilize the larger percentage of the nitrogen when its content is low would result in inhibition of growth in the shoot meristem. Plants that displayed bud inhibition consistently showed a more or less well developed root system. This might be evidence substantiating this explanation.

Cuttings selected from current wood responded more favorably to all the treatments given from the standpoint of both greater rooting percentages and shoot production. Terminal and lateral buds of current growth showed no difference in performance.

Cuttings of Ilex species treated with solutions were dwarfed and produced a heavy set of parthenocarpic fruit. Further experiments might substantiate the suggestion that these cuttings could be grown commercially in this manner for potted plant sales at Christmas.

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Effect of Certain Chemicals on the Germination of Crabgrass Seed When Plants are Treated During the Period of Seed Formation[1]

By J. A. DeFrance, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

CRABGRASS is a summer annual and is considered to be the most difficult weed to control in lawns, putting greens, and other turf areas. It is on the increase and is now acclaimed to be Enemy Weed No. 1. Its appearance can be noticed rather late in the spring or early in the summer. When crabgrass dies out or is killed by frost it leaves brown and unsightly areas in the turf. It is a very rapid grower and becomes difficult to control if it is not attacked in the young stages of growth. Young crabgrass plants are very shallow rooted and may be removed easily with the thumb and forefinger. If this hand weeding is not done, or if the young plants are not killed with chemicals, or by some other means, then an attempt should be made to keep the plants from going to seed as control is largely a matter of the prevention of seed formation for reinfestation and the spreading of seed to other areas.

If the season's crop of crabgrass would germinate all at once instead of having a prolonged germination period from April until the middle of September, the plants could be killed in the seedling stage by certain chemicals with one treatment as discussed by Robbins, Craft and Raynor (10) and DeFrance (3); but many treatments are necessary if the successive crops of seedlings are to be eliminated. Therefore, it was considered imperative and practical to determine a satisfactory time and method whereby minimum treatment could be employed.

Most lawn owners do not notice or think to control crabgrass until late in the season when it appears as a bronzy, reddish-purple mat of tangled, wiry, finger-like, seed-bearing stems many of which stand erect or spread out above the lawn grasses. However, many of the seed heads lie close to the ground and thus escape the cut of the lawn mower. Thus, a logical time for practical treatment with chemicals appears to be during the period of seed formation.

Tests with chemicals such as sodium chlorate, sodium arsenite, sodium fluoride, and Lawn Sinox at various rates of application for weed control in lawns have been reported by Grau (4, 5), by Monteith and Bengtson (8), by Marcovitch (7), by Robbins, Craft and Raynor (10), and by DeFrance (2, 3) with varying degrees of success, but no data appear to be available on the control of crabgrass by treatments at the time of seed formation.

Welton and Carroll (11) noted that applications of lead arsenate at the rate of 20 to 25 pounds per 1,000 square feet usually gave almost complete control of crabgrass, but the lead arsenate injured bluegrass somewhat. The brownish appearance did not develop until a year or more after application, and the quantity of growth was reduced 31 and 20 per cent the second and third years, respectively, after treatment.

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[1] Contribution No. 630 from the Rhode Island Agricultural Experiment Station, Rhode Island State College, Kingston.

Results of a test at the Rhode Island Agricultural Experiment Station to control crabgrass with arsenate of lead by treatment of turf areas that were heavily infested with crabgrass seed showed by unpublished data that applications of 25 pounds per 1,000 square feet gave 53.4 per cent control; 10 pounds gave 37 per cent control and 5 pounds gave 20.4 per cent control over the check plots. It was noted that the crabgrass plants on the plots that received 25 pounds were small and stunted. It was noticed also where arsenate of lead had been used continuously with yearly applications at the 4.5 and 9 pound rate that definite injury to the turf occurred. The most serious injury was on plots with acid soil. Due to the turf injury and the large amount of arsenate of lead necessary to control crabgrass it appears impracticable to use the material for that purpose. As reported by DeFrance (1) the weed control tests at the Rhode Island Agricultural Experiment Station with arsenate of lead were discontinued because of the harmful effects to the grass undoubtedly caused by the accumulation of the chemical in the soil. DeFrance (2) also states that arsenate of lead was effective for chickweed control but it appears that such large quantities are necessary for crabgrass control that its use is questionable for that purpose in view of the fact that such chemicals as sodium chlorate, sodium arsenite, and Lawn Sinox are giving good results when applied at suitable times.

Methods for the destruction of weed seed in soil with calcium cyanamid are given by Welton and Carroll (11); with chloropicrin by Monteith and Rabbitt (9); and by Howard and Stark (6). These methods help to produce weed-free topsoil prior to seeding, but are not so useful on established turf where permanent turf injury is to be avoided.

METHODS AND MATERIALS

The lawn selected for this test consisted of a mixture of Chewing's fescue, Kentucky bluegrass, Colonial, and Velvet bent which was quite uniformly and heavily infested with crabgrass. The area was 80 feet long by 50 feet wide and was divided into 40 plots, each 10 feet by 10 feet to give an area of 100 square feet to each plot. Treatments were applied to duplicate plots termed series A and B, and two plots were not treated and served as checks. A composite sample taken before treatment showed the acidity of the soil to be pH 5.1.

The materials and rates of application used in this test were based on the results of several previous tests, at the Rhode Island Station, for weed control and the effect of the treatment on turf injury. On established turf the problem in the control of weeds with chemicals is to kill the weeds without any serious permanent injury to the turf grasses. The materials used and rates of application are given in Table I. Treatments were applied September 8, 1941, when the majority of the crabgrass plants appeared to be mature and were in the process of seed formation.

On September 22, which was just 2 weeks after treatment and

TABLE I—MATERIALS USED, RATES OF APPLICATION, AND RESULTS OF TREATMENTS AS SHOWN BY PER CENT OF GERMINATION OF CRABGRASS SEED FROM PLANTS TREATED DURING PERIOD OF SEED FORMATION

Series		Materials* Used	Rate Per 1000 Square Feet	Gallons of Water Used for Spray	Number of Seeds Germinated‡ Total	Germination (Per Cent)
A Plot	B Plot					
1	21	Lawn Sinox 2 per cent	1.6 pints Sinox	10	3	1.5
2	22	Lawn Sinox 2 per cent + S/A**	1.6 pints Sinox + 1 pound S/A	10	4	2.0
3	23	Lawn Sinox 1 per cent	0.8 pints Sinox	10	3	1.5
4	24	Lawn Sinox 1 per cent + S/A	0.8 pints Sinox + 1 pound S/A	10	5	2.5
5	25	Milarsenite	10 pounds	none§	4	2.0
6	26	Milarsenite	15 pounds	none	3	1.5
7	27	Sodium Arsenite	2 ounces	10	7	3.5
8	28	Sodium Arsenite	3 ounces	10	1	0.5
9	29	Sodium Chlorate	1 pound	10	0	0.0
10	30	Gone with the Wind	9 ounces	7.5	1	0.5
11	31	Sodium Fluoride 2 per cent	800 grams + 400 grams soap	10	1	0.5
12	32	Sodium Fluoride 1 per cent	400 grams + 400 grams soap	10	2	1.0
13	33	Lawn Sinox 1 per cent	1.2 pints	15	2	1.0
14	34	Lawn Sinox	1.2 pints + 1 pound S/A	15	3	1.5
15	35	Lawn Sinox 1 per cent + S/A	0.8 pints	10	6	3.0
16	36	Zotox	4 ounces	5	1	0.5
17	37	Lawn Sinox A 1 per cent†	0.8 pints	15	5	2.5
18	38	Lawn Sinox A 1 per cent + S/A	0.8 pints + ½ pound S/A	10	6	3.0
19	39	Sodium Arsenite + Sodium Chlorate	1 ounce Sodium Arsenite + 1 pound Sodium Chlorate	10	1	0.5
20	40	Check (no treatment)		—	55	27.5

*Commercial materials used were Lawn Sinox from Standard Agricultural Chemicals, Inc., Hoboken, New Jersey; Milarsenite from Milwaukee Sewerage Commission; Gone with the Wind from Barteldes Seed Co., Denver, Colorado; Zotox from Garden Products Co., St. Louis, Missouri.

**Sulphate of Ammonia for use as an activator.

†Special Sinox supplied by manufacturer.

‡Results of duplicate treatment, (A & B series) 200 seeds planted from each treatment.

§Applied dry.

previous to any frost, the seed heads of the crabgrass plants were collected from the various plots and placed in individual containers to air dry. In November the seed heads were threshed, and clean seed was obtained. One hundred seeds from each experimental plot were selected and mixed with a small amount of clean sharp sand and placed in individual 1-pound coffee cans about 4 inches high and 6 inches wide.

In order to break the period of dormancy of the seed the open receptacles with contents were placed out-of-doors in an unprotected location and subjected to the natural climatic factors during the winter and early spring. Afterwards, the seed was planted in flats of sterilized soil. The flats were placed on the ground and the seed was allowed to germinate.

RESULTS AND DISCUSSION

The results of these tests are given in Table I and show that treatment with all of the different chemicals and commercial preparations used at the time of seed formation had a definite effect on decreasing the percentage of germination. It can be noted that germination of the seed from the check plots was 27.5 per cent and that germination of seed from the treated areas ranged from 0 to 3 per cent. The considerable difference between the percentage of germination of seed from the check plot and the plots that were treated shows that all treatments were beneficial in decreasing the viability of the seed and that only one treatment applied during the period of seed formation was quite effective.

None of the seeds from the sodium chlorate plots germinated. No germination occurred with seeds from series A on plots treated with sodium arsenite at the 2 ounce rate, Gone with the Wind, sodium fluoride 2 per cent, or from series B treated with a 1 per cent solution of Sinox A at the 10 gallon rate, Zotox, Lawn Sinox 1 per cent at 10 gallons plus ½ pound sulphate of ammonia, or with the mixture of sodium arsenite and sodium chlorate.

The fact that only 27.5 per cent of the seed from the check plots germinated in this test conducted out-of-doors is not disturbing in view of the fact that the flats were not kept continually moist nor at optimum conditions for germination of crabgrass seed. Welton and Carroll (10) reported 61 per cent and 41 per cent germination of large and small crabgrass respectively in a greenhouse test where they were determining the effectiveness of a certain chemical in killing weed seeds. They also stated that there was a period of dormancy, the duration of which lasted from 3 to 6 months; and no seed germinated where the moisture content was less than 10 per cent.

A few days after treatment, it was noticed that the lower portion of some of the seed heads had been protected by the sheath at the time of spraying and were apparently uninjured. This may account for some of the viable seed and would also indicate that a second treatment would be advisable if seed heads had not emerged entirely at the time of treatment. The time of spraying is important especially where only one treatment may be given. Spraying should be done before the seed matures and falls to the ground and after the seed has emerged from the sheath.

The time of fertilization is a factor in the control of crabgrass. By fertilizing in the fall after crabgrass has ceased growth or has been killed by chemicals or frost, and also by fertilizing in the spring before crabgrass gets a start, the permanent lawn grasses will be stimulated and consequently will help to crowd out crabgrass.

Summary and Conclusions

The results of this study show a very substantial decrease in the percentage of germination of crabgrass seed when plants were treated at the time of seed formation with certain chemicals and commercial preparations at the rates used in this test.

The materials used were sodium arsenite, sodium fluoride, sodium chlorate, a mixture of sodium arsenite and sodium chlorate, Lawn Sinox, Milarsenite, Gone with the Wind, and Zotox.

This method should be of considerable benefit in the control and eradication of crabgrass in lawns and other areas. The idea should not be conveyed that this method is recommended as a "cure-all" for the crabgrass problem because there are methods of culture such as: hand weeding, method of cutting, height of cut, time of fertilization and treatment of young plants that aid in the control of crabgrass. However, if these measures are neglected and crabgrass reaches maturity, then the method reported here should be of use. It is a simple, practical and comparatively inexpensive method that can be employed by home owners or others interested in weed control at a time when they are well aware of the presence of crabgrass.

The materials at the rates used were also effective in helping to control dandelion, plantain, chinquefoil, chickweed, hawkweed, healall, and sorrell.

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The Killing of Weed Seed in Compost by the Use of Certain Fertilizers and Chemicals[1]

By J. A. DeFrance, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

COMPOST free of viable weed seeds is very desirable. Good clean compost is needed for use in greenhouses, for tobacco and other seed beds, for the topdressing of fine turf areas, and for use in other places where the weed situation causes concern. The problem of the most efficient and economical method for the destruction of weed seed in soil or compost is an important factor.

Previous methods of soil sterilization by the use of steam (5) and electricity to generate heat sufficient to kill weed seeds; and chloropicrin (3, 4) have been employed at the Rhode Island Agricultural Experiment Station with varying degrees of success. Preliminary tests in 1934 with nitrogenous fertilizers indicated their possible use as weed seed eradicating agents. As a consequence four different sets of experiments were conducted over a period of seven years to determine the weed seed killing power of certain nitrogenous fertilizers mixed with the compost.

Experiments undertaken and the purposes of the tests were as follows:

1. Field test in a compost pile from 1935 to 1938, to determine whether nitrogenous fertilizers would destroy seed of weeds, grass and clover when mixed with compost or soil in a pile under field conditions.
2. Greenhouse tests in open-top cardboard containers during 1939–40, and in 1942, to determine:
   - a. The necessary amounts of nitrogenous material to be mixed with compost to destroy weed, grass and clover seed in a relatively short time where temperature and moisture conditions were fairly uniform.
   - b. To note differences in temperature created by the mixtures.
3. Tests in wooden bins in the compost shed during 1942, designed to increase the volume of material treated and to approach more practical working conditions; and also to determine how turf would respond when topdressed with the different compost-fertilizer mixtures.

REVIEW OF LITERATURE

In a search through scientific publications, no reference was found to a method of killing weed seed in compost by the use of nitrogenous fertilizers. However, Welton and Carroll (6) reported, "under conditions other than a compost pile, as on lawn areas—among the various materials used at the Ohio Station, Cyanamid was the most effective topdressing agent. Applications made at the rate of 20 pounds per 1000 square feet and worked into the surface soil gave fairly satisfactory control of many of the more common lawn weeds. For plantains and many of the annuals like foxtail and crabgrass, however, 40 pounds per 1000 square feet did not give complete control, although most of the weed seeds were killed." These workers also treated a portion of a compost pile with chloropicrin at the rate of 25 ounces per cubic yard. They state, "In this test the seeds of lamb's quarter were highly resistant to chloropicrin; so were those of orache and White Clover". In fact they recorded 54 plants of White Clover in untreated compost whereas there were 66 in the treated compost.

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[1] Contribution No. 643 of the Station.

MATERIALS, METHODS AND RESULTS

1. *Field Test:*—In November 1935 eight treatments were employed in duplicate, using the following materials and number of pounds of nitrogen on the cubic yard basis: Milorganite 5 and 15, cottonseed meal 15, Cyanamid 1 and 5, ammonium sulfate 15, all mixed with compost made of three parts soil and one part sand; ammonium sulfate 15 with two parts soil, one sand, one manure; and ammonium sulfate 15 with two parts soil, one sand, one granulated Swedish peat. To the ammonium sulfate treatments an equal number of pounds of ground limestone were added to help neutralize the acidity from the ammonium sulfate. The 16 lots of compost were mixed separately with measured amounts of the fertilizer materials. Likewise, 16 batches, each made up of one pint of weed seed and Rhode Island bent grass seed obtained as screenings from a grass seed cleaning process were mixed with 2 shovelsful of compost and placed in containers made of window screen. Sixteen 2-bushel burlap bags were filled one-third full of the compost-fertilizer mixture. The batches of the seed and compost mixture were placed on top of this and the bags were then filled to two-thirds full with more of the compost-fertilizer mixture and buried throughout a compost pile at regular intervals. The compost pile had been built recently of two parts loam, one part cow manure, one part clean sharp sand, and measured 20 by 20 feet square and was 5 feet high.

On the basis that good compost pile management would necessitate the construction of the pile a few years in advance of use, it was left undisturbed until August, 1938, samples were obtained from the variously treated composts and placed in flats in the greenhouse where conditions were made favorable for the germination of the viable seeds. Notes on number and kind of weeds and grasses were taken every three weeks.

The use of Milorganite at the rate of 15 pounds N per cubic yard gave complete kill of all weed and grass seed but the 5 pound rate in this test had no noticeable effect. Cottonseed meal and Cyanamid were very effective at the rates used. Ammonium sulfate at 15 pounds N in this test had but little effect on the kill of weed and grass seed and no significant differences were obtained between composts made up with peat moss, or with manure, or of only soil and sand. The total weed count per flat where manure was used was 160, with peat 117 and with soil and sand 131.

2. *Greenhouse Test No. 1:*—The fertilizers used in this treatment of compost were Milorganite, Agrinite, Cyanamid, and ammonium sulfate.

The compost was a mixture of two parts loam, one part manure, one part sand, screened through quarter-inch wire mesh. The fertilizers were weighed out and mixed thoroughly with the compost. Three grams of weed seed, 2 grams of clover seed, and 1 gram of Rhode Island bent seed were thoroughly incorporated with the mixture. This mixture was placed in open-top containers about 1 foot square made of heavy cardboard coated with wax and designed for packing gallon containers of ice cream. The bottom and top 2 inches were not mixed with the seed but consisted of the fertilizer-loam mixture. The containers were placed side by side on a propagating bench and covered with moist newspapers and burlap bags to help prevent evaporation and radiation. The average temperature in the greenhouse was about 75 degrees F. Daily temperature readings were taken of the various treatments. Milorganite at the rate of 15 pounds N per cubic yard caused the greatest rise in temperature, developing heat to 130 degrees F, an increase of 55 degrees which remained for a period of approximately thirty hours. Agrinite developed a temperature of 105 degrees F. After a period of 2 weeks, the contents of the containers with the exception of the bottom and top 2 inches were put in flats and watered. The four nitrogenous fertilizers used in this test appeared to be of considerable value for the purpose of killing weed seed in compost. The results of the treatments are shown in Table I.

TABLE I—COMPOST TREATMENT, MATERIALS AND RATES OF APPLICATION, TEMPERATURES OBTAINED AND RESULTS OF TEST AS SHOWN BY AMOUNT OF WEEDS PRODUCED FROM TREATED COMPOST (GREENHOUSE TEST No. 1, 1939–1940)

Materials	Nitrogen per Cubic Yard (Pounds)	Fertilizer per Cubic Yard (Pounds)	Average Maximum Temperature (Degrees F)	Number of Weeds in Flats*			
				May 25	May 29	June 3	June 24
Milorganite	5.0	83	105	0	0	0	0
Milorganite	10.0	166	115	0	0	0	0
Milorganite	15.0	249	130	0	0	0	0
Agrinite	5.0	58	90	0	0	0	0
Agrinite	10.0	116	95	0	0	0	0
Agrinite	15.0	174	105	0	0	0	0
Cyanamid	0.55	2.5	75	43	72	135	141
Cyanamid	1.10	5.0	75	0	0	0	0
Cyanamid	5.0	22.0	75	0	0	0	0
Ammonium sulfate	16.0	75†	75	0	0	0	0
Check	0	0	75	105	137	190	195

*Compost placed in flats May 15.
†An equal number of pounds of ground limestone were added to the sulfate of ammonia to help neutralize the acidity from the ammonium sulfate.

Greenhouse Test No. 2:—This test was started March 2, 1942 using the same kind of materials but at slightly different rates of nitrogen, the same amount of seed, and the same kind of containers as in the previous test. The fertilizers were thoroughly mixed with the compost in each container, and the seeds were thoroughly mixed with the compost-fertilizer mixture of each container except for the bottom and top two inches. The containers were placed in cement beds 6 feet long and 3 feet wide and deep enough so that their tops were flush with the top of the beds. An insulating layer of peat moss was placed around the containers in order to eliminate heat conduction between the mixtures. The average temperature in this greenhouse was 58 degrees F.

Results of this test are shown in Table II. Temperatures of each container were taken daily. The maximum temperatures were recorded the seventh and eighth days. Milorganite at the rate of 5 pounds of N per cubic yard gave a 24 degrees rise, and a 14 degrees increase with the 3 pound rate; Agrinite at 3 pounds gave an increase of 7 degrees, and at 5 pounds a 9 degrees increase. Very little or no increase was recorded for Cyanamid, sulfate of ammonia and lime, or Chloropicrin.

TABLE II—Compost Treatment, Materials and Rates of Application, Temperatures Obtained, and Results of Test as Shown by Amount of Grass, Clover, and Weeds Produced from Treated Compost (Greenhouse Test No. 2, 1942)‡

Materials	Nitrogen per Cubic Yard (Pounds)	Material per Cubic Yard (Pounds)	Average Maximum Temperature (Degrees F)†	Germination in Flats (Per Cent)			Response of Bent Grass* Planted
				Weeds	Grass	Clover	
Milorganite	3	50	72	55	19	2	Good
Milorganite	5	83	83	0	1	1	Poor
Agrinite	3	37	66	56	30	4	Good
Agrinite	5	62	70	15	6	1	Fair
Calcium Cyanamid	1.05	5	60	0	1	3	Poor
Calcium Cyanamid	3.15	15	60	0	0	0	Dead
Ammonium Sulfate	5	25**	60	0	1	0	Dead
Ammonium Sulfate	10	50**	59	0	0	0	Dead
Chloropicrin	0	1	59	3	72	140	Good
Check	0	0	59	100	100	100	Good

*Treatment started March 2.
**An equal number of pounds of ground limestone added.
†Maximum temperature reached 7th and 8th days.
‡Two bent grass plants planted in each flat March 27, observations recorded March 30.

The treated compost was transferred to flats, March 23. In order to note any remaining killing power of the materials, two fairly mature plants of Rhode Island bent that had a spread of about 4 inches were planted in each flat, March 27. Three days afterward, March 30, the plants on the 3 pound rate of Cyanamid, 5 and 10 pound rates of sulfate of ammonia and lime were flaccid, brownish and dead. On the 1-pound mixture of Cyanamid, they were poor, but on the others were fair to good and remained so. Milorganite at the rate of 5 pounds of N, Cyanamid at the 3.15 pound nitrogen rate and the combined sulfate of ammonia and limestone gave very satisfactory kill of weed seeds. Chloropicrin at the rate of one pound per cubic yard apparently had no effect on killing clover seed, but rather produced increased germination (6).

3. *Tests in Wooden Bins in the Compost Shed:*—These tests were started June 11, 1942. The materials used, rates of application, and results are given in Table III. Tests were run in duplicate in bins that held 3 cubic feet. After the fertilizer materials were thoroughly incorporated with the compost, 15 grams of weed seed, 7 grams of white Dutch clover and 3 grams of Rhode Island bent seed were mixed with

TABLE III—Compost Treatment, Rates of Application of Materials and Results of Tests as Shown by Percentage of Control of Weed Seeds, Temperatures Obtained, and the Effect of Treated Compost on Putting Green Turf (Bin Test, 1942)

Materials	Nitrogen per Cubic Yard (Pounds)	Material per Cubic Yard (Pounds)	Maximum Temperature Recorded June 17§ (Degrees F)	Per Cent Control of			Color Increase on Bent Grass‡	
				Weeds	Grasses	Clover	Creeping	Colonial
Milorganite....	5	83	104	95	97	100	100	100
Agrinite .	5	62	97	95	97	100	83	100
Calcium Cyanamid	1	5	76	98	99	96	50	57
Calcium Cyanamid	2	10	72	100	99	99	66	71
Ammonium Sulfate	5	25*	72	100	100	100	100	86
Chloropicrin	0	1	71	99	99	0	33	29
Check.. . .	0	0	71	0	0	0	33	29**
							0	0†

*An equal number of pounds of ground limestone were added to help neutralize the acidity from the ammonium sulfate.

**Untreated compost.

†No compost.

‡From application of treated compost applied to putting green turf as topdressing one month after treatment.

§Experiment started June 11, 1942.

the compost-fertilizer mixture and placed in the bins. Chloropicrin (3, 4) was added to certain bins at the rate of 1 pound per cubic yard. Temperature readings were taken daily, and the maximum was reached on June 17 which was 6 days after treatments were applied.

A temperature of 104 degrees F resulted from the use of 5 pounds of nitrogen from Milorganite, an increase of 33 degrees above the check. The 5 pound rate of nitrogen from Agrinite generated a temperature of 97 degrees, an increase of 26 degrees, and slight increases in temperatures were recorded for the other fertilizer treatments but not for Chloropicrin. On July 14, samples of the treated compost were placed in flats and taken to the greenhouse. The per cent control of weed, grass, and clover seed of the variously treated lots are shown in Table III. All treatments gave at least 95 per cent kill of weed seeds. The mixture of sulfate of ammonia and limestone gave perfect control of weed, grass and clover seed. Milorganite and Agrinite killed the clover seed. Cyanamid killed most of the clover but Chloropicrin did not seem to kill clover seed as there appeared as much clover on the Chloropicrin treated compost as on the checks.

In order to determine if there would be any detrimental effect from the use of the variously treated composts on putting green turf, they were applied as topdressing at the rate of ⅕ cubic yard per 1000 square feet on July 14, a month after treatment, to plats of creeping bent, and Colonial bent. Within 3 days after the compost was applied, there was marked increase in growth and color. The compost treated with sulfate of ammonia gave the quickest response. Two weeks after the topdressing was applied, notes were taken on the increase of color. The percentage of increase is shown in Table III. It can be noted that all treated composts except with Chloropicrin gave considerable response when applied as topdressing. No available nitrogen in Chloropicrin could account for this. No harmful effects were observed from any of the applications.

Temperatures of 160 to 170 degrees F were obtained in compost piles consisting of 10 to 15 cubic yards when mixed with Milorganite at the rate of 15 pounds of N per cubic yard of compost during August and September of 1942. In the compost mixture where the nitrogenous fertilizer may create a high temperature there is a possibility of loss of ammonia, although no such loss was noted in any of these tests. Certain of the organic fertilizers generated such high temperatures in such a short time that it appears that these sources of nitrogen may be dangerous if applied alone in very large quantities on turf especially during hot, humid, rainy periods of July and August, or just prior thereto, and might possibly cause injury called "scald" of grass. This condition has been reported by DeFrance and Erwin (1, 2).

It appears that when nitrogenous fertilizers have the ability to create an extremely high temperature, with the help of bacteria, fungi, and moisture, the temperature should not be allowed to exceed a point where any form of nitrogen might be lost or given off in the atmosphere.

Summary and Conclusions

The results of these experiments show that the method of killing undesirable weed seeds in compost by mixing the compost with certain fertilizers that contain nitrogen is of considerable value. It is practical as well as economical and will provide compost relatively free of viable weed seeds.

Comparatively high temperatures were obtained by the use of organic nitrogenous fertilizers. At rates of 15 pounds of nitrogen per cubic yard, Milorganite developed a temperature of 130 degrees F and Agrinite 105 degrees F in lots of about 1 cubic foot, and to 160 to 170 degrees F in lots of 10 to 15 cubic yards. But satisfactory kill of weed seeds was obtained by the use of either organic or inorganic nitrogenous fertilizers without the generation of such high temperatures. Consequently lesser amounts of nitrogen were needed to kill weed seeds.

Little or no increase in temperature occurred from the use of inorganic nitrogenous fertilizers such as Cyanamid, and ammonium sulfate and limestone. It appears that weed seed can be killed in compost with some of the fertilizers without generation of heat. It is also apparent that it is not the heat alone that does the damage to weed seeds.

Whether or not the compost-organic fertilizer mixture is covered with a canvas or other material will make a difference in the amount of heat accumulated. The moisture content is undoubtedly a factor that should be considered and controlled when treatment with organic nitrogenous fertilizers is undertaken for the purpose of soil sterilization.

The method is both practical and economical from the greenkeeper's standpoint because both sterilized compost and fertilizer may be applied as topdressing at the same time in one operation. This would save considerable of the time involved in making two separate applications of compost and fertilizer, especially during periods of labor shortage. This method would also have a tendency toward a more uniform distribution of fertilizer and, according to these tests, there was considerable benefit and no harmful effects on established turf when topdressed with compost treated with the various fertilizer materials used at the rates employed.

In view of the scarcity of inorganic nitrogen due to its demand for use in munitions during war times, it is imperative to substitute organic nitrogenous fertilizers. It is fortunate that they can be employed for the dual purpose of soil sterilization and fertilization.

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